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Disruptive Classroom Technologies

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Summary and Keywords

Of the many stated purposes of organized educational systems, one that might meet with general agreement is this: to ensure students build abundant learning capacity, achieve ample academic proficiency, and consolidate the requisite knowledge, skills, and aptitudes to successfully address future learning challenges. As computer technologies have transformed nearly every human endeavor imaginable, future learning challenges that students encounter will almost certainly require facility with digital technologies. In the realm of teaching and learning, the average impact of computer technology on student achievement has been both negligible and unchanged, despite astonishing technological developments since the 1960s.

However, there is cause for renewed optimism about technology use in education. Compounding evidence suggests that large gains in student achievement are possible when digital tools are leveraged to enhance highly reliable instructional and learning strategies. The objective of the author's investigation efforts is to develop a more precise language and set of ideas to discuss, enact, and evaluate high impact uses of digital tools in education. The result is the T3 Framework for Innovation in Education. The T3 Framework increments the impact of technology use into three hierarchical domains: Translational, Transformational, and Transcendent. Compounding evidence suggests that implementing the strategies in the T3 Framework, with reasonable fidelity, will likely increase the impact of digital technologies to unlock students' limitless capacities for learning and contribution, and better prepare today's students for tomorrow's learning challenges.

Keywords: disruptive innovation, T3 framework, educational technology, computers in education, translational technology use, transformational technology use, transcendent technology use, inquiry design, social entrepreneurship, student achievement

Present and Future Readiness

Modern educators are tasked with the extraordinarily arduous responsibility of facilitating student learning in the present moment while simultaneously helping students to consolidate the knowledge, capabilities, and mindsets to successfully address future learning challenges. John Dewey (1938) keenly observed the importance of present and future learning readiness during the rise of the industrial revolution—observations which are just as applicable amidst the ascent of the digital revolution.

Dewey’s (1938) principles of continuity and interactivity elucidate the inherently iterative and interconnected nature of pedagogical systems and the contexts in which that learning takes place. The principle of continuity posits that all of one’s past experiences are carried forward and exert an influence on both current and future experiences and decisions (Dewey, 1938, p. 35). Dewey’s principle of interaction refers to the conditional relationships that exist between the learner, the new knowledge that the learner experiences, and the environment in which that interaction takes place (Dewey, 1938, p. 42).

These two principles, while distinct, are highly correlated and relevant to any learning context, past, present, or future. A student’s current learning at any moment is the sum total of all their prior experiences, which in turn exert an inextricable influence on their future learning. Dewey (1938) suggests that the effectiveness of students’ learning experiences in classroom environments are not only impacted by each learner’s own unique background knowledge, interests, and sense of personal purpose, but must also be conducive to developing the skills, competencies, and aptitudes necessary to thrive in the world outside the classroom. These two principles also serve as a reasonable foundation for considering how organized educational systems might realize their collective purpose in the burgeoning digital age.

In order to meaningfully consider effective pedagogical methods, one must take into consideration the larger context in which learning environments exist. The digital age has arguably given rise to drastic changes in the way we live, learn, and work. Our world is becoming increasingly globalized through the advent of information and communication technology, and this explosive growth will likely increase rather than abate (Merriam, Caffarella, & Baumgartner, 2007). A learner entering K-12 education systems in the digital age will arguably need to gain more knowledge and master more skills than any previous generation in order to navigate the growing complexities of life and work in the digital age. Maintaining a continuity of experiences for digital age learners is a function of intentionally aligning learning experiences, knowledge-focused conversations, and interactions within their classroom to better prepare them for the highly uncertain future that exists outside those walls (Magana & Frenkel, 2010). As computer technologies have transformed nearly every human endeavor imaginable, future learning challenges that students encounter will almost certainly require agile and adaptive use of digital technologies. Education systems have responded in kind as evidenced by the rapid growth of computer and Internet technologies in K-12 education. The average number of computers designated for instructional use in public schools rose from 72 to 189 computers per school between 1995 and 2008, while Internet access in schools during the same 13-year period rose from 8% to a staggering 98% (Downes & Bishop, 2015; Snyder & Dillow, 2012). Additionally, significant investments have been made in teacher and administrator training in an effort to improve teachers' confidence and competence with using digital tools (Demetriadis et al., 2003; Gray et al., 2010; Inan & Lowther, 2010; Staples, Pugach, & Himes, 2005).

However, despite the tremendous growth in computer technology and Internet access and training on using digital tools in schools, the role that technology should play in the context of teaching and learning is not yet well understood. In fact, the preponderance of evidence suggests that the effect of digital tools on student learning is downright negligible (Cheung, Slavin, 2011; Cuban, Kirkpatrick & Peck, 2001; NEA, 2008; Richtel, 2011; Hattie, 2008; 2012; 2017; Higgins et al., 2012).

Learning systems have yet to realize the potential of technology to prepare students to master current learning problems and gain the skills necessary for success in the digital world. In their first assessment of digital skills, OECD (2015) reported that countries which have invested heavily in educational technologies saw no noticeable improvement in student performances in PISA results for reading, mathematics, or science (OECD, 2015). Moreover, in their recent review of influences impacting instructional quality, Coe et al. (2014) do not support investment in digital technologies as a means for either improving teaching practices or learner outcomes (Coe et al., 2014).

The effective integration of digital tools to reliably improve teaching and learning constitutes a significant problem facing educational systems in that it is a highly complex, multifaceted, ill-structured, ill-defined, and as yet unresolved problem. The nature of this problem has largely been overshadowed by a pervasive systematic error—a value-positive bias—that was born in the overly optimistic era when educational technology systems were first sold on the digital promise of educational transformation by the mere presence of computers in schools (Magana & Marzano, 2014).

A Wicked Problem Emerges

The author's focus on researching the impact of educational technology began in earnest in 1984 while a graduate research student at Rutgers University in New Jersey. Rutgers University had recently furnished a new computer lab with Apple IIe personal computers and was among a wave of research institutions exploring the potential uses of personal computers to improve learning. A class of students from a local middle school was selected to become the subjects of a proposed study to determine the relationship between computers and student engagement. As investigating the effects of personal computers on student learning was so novel, the researchers clumsily followed a "Let's add the technology and see what happens" protocol.

The study subjects were asked to collaboratively solve “The Oregon Trail,” a learning game that was developed by the Minnesota Educational Computer Consortium. There was a great deal of excitement displayed by the students and researchers alike at the prospect of observing futuristic, if not Orwellian, learning first hand. The general assumption was that student engagement and learning would automatically be transformed by the wondrous experiences that would surely take place with computers. This was the author’s first conception of the confounding effects of a value-positive bias, or “digital promise,” which skews one’s perspective when observing phenomena related to teaching and learning with digital tools.

The protocol of the study was relatively straightforward. Over the course of several weeks, the researchers were to observe the nature of student interaction with the software program and code their level of engagement as 3), High, 2) Medium, and, 1) Low. At the start of the study, when students were first introduced to the program, all of the coders unanimously rated student engagement as high. This level of engagement was maintained as students learned the basic operations of the floppy disks, the disk drive, the computer screen, directional arrows, and the all-important space bar. Student engagement was also high as the subjects began playing the game.

After a few weeks, the researchers began to notice something strange: the student subjects became bored. As their boredom increased, the subjects began to display disruptive behavior in the computer lab. The researchers recognized a precipitous drop in student engagement over a relatively short period of time. As the initial novelty of the computer and software began to wane, student interest, as demonstrated by their observed level of engagement, also began to wane. Students began to spend more time in the arcade game portion of the program, in which they could hunt for food by firing a virtual rifle at “game” on the trail.

Serious flaws in the study were recognized and discussed. There was no control group from which to draw reasonable comparative analysis. The researchers were not actually seeking to observe the impact of technology on authentic student learning of academic content, but were rather observing evidence of student engagement behaviors. There was no appreciable way of reconciling what students learned, or if anything actually was learned, let alone if that learning was effectively transferred to some other academic content. The researchers could not determine whether the learning that occurred through the computer game was more effective than learning about the Oregon Trail using other more traditional instructional methods. Rather than ascertaining meaningful learning impact, such as a pre-/post-assessment of student gain in academic content as the object of the study, the technology itself became the object of the study. Could the initially high level of student engagement have been caused by the novelty of the computer itself? That question raised another far more profound question, Was the use of computers in schools a means towards epistemological ends, or an end unto itself?

The pattern that was observed at Rutgers in 1984 played itself out again and again over the course of the following 34 years. The technological novelty effect expressed by Clark

(1983, 1985, 1994) has been enacted many times, putting educational systems on a kind of novelty conveyor belt. Students are introduced to a new technology, the novelty of which causes a sudden spike in engagement, then a noticeable and observable drop in engagement follows until the next new technology tool is purchased. The engagement study at Rutgers presaged an insidious pattern where educational technology tools are acquired, students get “wired,” and then get mired until some other digital tool is acquired. Little or no significant impact on student achievement has come from the incessant novelty conveyor belt upon which education has found itself woefully trapped.

This pattern has resulted in a pervasive view that computers should be separate from the processes of teaching and learning; many schools relegate computers to “play stations” in the backs of classrooms where students are rewarded with computer play time after completing their classwork (Cuban, Kirkpatrick & Peck, 2001). This is hardly cause for optimism. Moreover, teachers have not been adequately trained, according to a recent survey by the National Education Association (NEA) that sought to ascertain teachers’ uses of computers in their classroom. Their findings concluded, “we have few assurances that [educators] are able to use technology for teaching and learning” (NEA, 2008, p. 1).

Effective and reliable integration of digital tools to enhance teaching and learning in schools could thus be characterized as a “wicked problem” (Rittel & Webber, 1973). Wicked problems are ill-structured, poorly understood, highly complex, intractable, and as yet unsolved. This is an apt description for the problem of reliably harnessing the potential of digital tools to accelerate student learning. There are too many influencing variables, too many digital tools to consider, too many ways in which those tools may be wielded by teachers and students, and far too much evidence-free propaganda confounding our thinking about what works and why it does.

However, there is cause for renewed optimism. Compounding evidence now suggests that large to very large gains in student achievement are possible when digital tools are leveraged to enhance highly reliable instructional and learning strategies (Haystead & Marzano, 2009; 2010; Haystead & Magana, 2013; Magana & Marzano, 2014; Magana, 2016; Magana, 2017).

Pedagogies of the Past and Technologies of the Present

To the extent that technology is actually used in the teaching and learning process, educational systems seem to have arrived at an unhappy juncture where computer technologies are predominantly used as either a replacement for a human teacher or to supplement teachers’ administrative tasks, such as communicating, testing, budgeting, word processing, and presenting information (NEA, 2008). In order to better understand the juxtaposition of modern technologies with current pedagogies, an overview of two extant educational models is warranted: Marzano’s (2007) instructional model, The Art and Science of Teaching, and Hattie and Donoghue’s (2016) Model of Learning. Both models are distilled from major reviews of research to identify what approaches have a reliably positive impact on teaching and learning. These models are also highly correlated and complementary as each addresses one side of the proverbial teaching and learning coin.

Marzano’s (2007) Art and Science of Teaching model articulates 41 elements of effective instruction that are categorized into three phases of instruction: 1) Interacting with new knowledge, 2) Practicing and deepening new knowledge, and 3) Generating and testing hypotheses about new knowledge. During the first phase, instructional methods are employed to present students with new learning content. These methods include previewing new content, chunking content into “digestible” bites, identifying critical information, and helping students reflect upon their learning (Marzano, 2007). The second phase contains methods to help students practice and deepen their understanding of new knowledge, including strategies to help students review and practice their skills and understanding both individually and in collaboration. The third and final phase involves having students generate and test hypotheses or claims about new content knowledge (Marzano, 2007).

Hattie and Donoghue’s (2016) Model of Learning closely aligns with Marzano’s (2007) Art and Science of Teaching model, but does so from the perspective of learning tasks conducted by students. For example, the learning model developed by Hattie and Donoghue (2016) includes three phases of learning: 1) Surface Learning, 2) Deep Learning, and 3) Knowledge Transfer. In the first phase, Surface Learning, students first acquire new content information that is presented to them by their teachers into their short-term memory. This is followed by a consolidation phase in which students actively practice and rehearse their superficial understanding of new content. At this first learning level, students interact with surface level knowledge such as basic facts about the new content, simple details, and new content-specific vocabulary.

In Hattie and Donoghue’s (2016) second phase, Deep Learning, students employ a variety of learning strategies to acquire a deeper understanding of new content. It’s important that students attain a sufficient number of learning strategies so they can apply a different strategy when a current strategy they are using is not working to deepen their understanding. Such self-regulated students, in effect, become their own teachers. They are able to set their own mastery goals, monitor and regulate their cognition, emotions, and learning behaviors as they progress towards their goals. These students are able to more precisely employ strategies to clarify, elaborate, and generate analogies and metaphors to express and represent their deeper understanding of new knowledge (Hattie & Donoghue, 2016; Magana 2017; Magana, 2018; Magana & Marzano, 2014; Marzano, 2007; Pintrich, 2000). Students who are successful working at the deeper learning phase also have a clear conception of success criteria and are able to more agilely store and retrieve knowledge into and from longer-term memory (Hattie & Donoghue, 2016; Marzano, 2010).

In the third phase, students consolidate their deep understanding into more permanent memory by applying, or transferring their newly acquired knowledge in different situations, contexts, or to solve new problems. Over time, students who are successful at transferring their knowledge in different contexts gain ample experience in determining the similarities and differences of concepts they are learning in the moment and in previously experienced contexts. As such, they can more readily discern which strategy they need to use to make sense of the new situation or problem. Such students approach a type of learning mastery by drawing from deep reservoirs of learning strategies that they can agilely and adaptively apply when necessary during the three different learning phases (Hattie & Donoghue, 2016; Magana, 2017; Magana, 2018).

This raises the question of how much instructional time teachers are spending on each phase of the teaching and learning. In a recent study Marzano and Toth (2014) analyzed over 2 million teacher observations that were videotaped to ascertain the percentage of instructional time teachers spent at each stage in the three domains of instruction: 1) Interacting with new knowledge (Surface Learning), 2) Practicing and deepening new knowledge (Deep Learning), and, 3) Generating and testing hypotheses (Transfer of Knowledge). Marzano and Toth (2014) found that, on average, teachers in the study spent 58% of instructional time presenting new knowledge to students (Surface Learning) and 36% of their time on managing students practicing and deepening their understanding of that new knowledge (Deep Learning). This left only 6% o f classroom instructional time for students to generate and test hypotheses about that knowledge (Transfer of Knowledge) (Marzano & Toth 2014).

These findings suggest a pedagogical trend that is decidedly weighted towards surface-level interaction followed by rote practice and memorization of that surface learning. Such instructional time management leaves insufficient opportunities for students to deeply consolidate their understanding by transferring their new knowledge to new situations. The “tell and practice” model has been the dominant instructional model for much of the 20th century, and continues unabated into the 21st century (Hattie, in Magana, 2017, p. i).

It is almost irrefutable that simply overlaying digital technologies onto the “tell and practice” model has had a trivial impact on student achievement (Coe et al., 2014; Hattie, 2008, 2012, 2017; Higgins et al., 2012). Meanwhile, information and communication technologies have had a systemic and transformative impact on nearly every other human endeavor imaginable (Magana & Marzano, 2014; McFarlane, 1997). Arguably, the increasing pace of globalization through technological advances necessitate a complete redefinition of what should be considered effective instructional practices in modern classrooms (McFarlane, 2015).

A reasonable inference can be made that the low impact of technology on instructional quality and student achievement is tied to at least two factors that are derived from the extant literature: 1) Digital tools are generally not used to directly enhance instruction and learning; and 2) When digital tools are used, they are employed to simply supplement the “tell and practice” model of teaching and learning (Cuban, Kirkpatrick & Peck, 2001; Hattie, 2017; Magana, 2017; McFarlane, 2015; NEA, 2008; Richtel, 2011).

While digital tools in schools have the potential to transform classroom teaching and learning, this potential has yet to be fully actualized. Effective and systemic technology integration in classroom instruction remains frustratingly elusive. Another contributing factor may be the popularity of a "replacement" model of technology integration. In the "replacement" model, instructional content and assessment items are delivered to learners by a computer terminal rather than by a human teacher (Jenks & Springer, 2002). An important trend from the research literature strongly suggests that using educational technology tools to replace a human teacher has a low impact on student academic performance (Cheung & Slavin, 2011; Cuban, Kirkpatrick & Peck, 2001; Hattie, 2008, 2012; Hsu, 2003; Magana, 2016; Magana & Marzano, 2014; Yaakub & Finch, 2001). The "replacement" model of technology integration may have contributed to the unhappy marriage of pedagogy and technology, and the unhappy offspring of this marriage.

McFarlane (2015) argued against simply replacing teachers with computers and online learning content, suggesting that educational technologies have much greater impact when they are incorporated into the context of what is currently considered effective instruction. She states:

> In reality much that we know about learning, communicating, creating knowledge and sharing it, remains valid in the face of connected digital technologies. Recognizing this and adapting effective practice to new contexts is at the heart of understanding how digital technologies can best support effective teaching and meaningful, authentic learning.
>
> (McFarlane, 2015, p. 15)

There have been several meta-analyses, or analyses of analyses, that have addressed the general effects of educational technology on student learning. The meta-analytical evidence is often quantitatively expressed as an effect size. Hattie (2008) posits effect sizes to be the most useful way of determining practices that positively impact student achievement. For example, effect sizes below 0.40 can be considered small or having minimal impact on student learning, while effect sizes near 0.6 can be considered moderate and sizes near 0.80 can be considered large, while those above 1.0 can be considered very large (Cohen, 1988; Lipsey, 1990). In short, the larger the effect size, the greater the impact of the intervention.

Computer-assisted instruction (CAI) technologies, perhaps the most popular application of the "replacement" model, has historically had a meager impact on student achievement. CAI has been defined as "a method of instruction in which the computer is used to instruct the student and where the computer contains the instruction which is designed to teach, guide and test the student until the desired level of proficiency is attained" (Jenks & Springer, 2002, p. 43). In essence, CAI technologies are, in fact, a direct replacement for a human teacher. The preponderance of evidence strongly suggests that the average impact of using technology to replace teachers is decidedly low (Azevedo, 2005; Barrow, Markman, & Rouse, 2008; Chambers et al., 2008; Cheung & Slavin, 2011; Hattie, 2008; 2012; 2017; House, 2002; Huang & Ke, 2009).

More recently, Hattie (2017) employed meta-analytical techniques to analyze 10, 226 studies addressing various applications of computers on student achievement. Hattie (2017) found the average impact of various aspects of computers student achievement to be ES = 0.34. By way of comparison, an effect size of ES = 0.40 represents the average amount of learning productivity gained over one academic year. Effect sizes above ES = 0.40 are clearly desirable, while effect sizes falling short of this average indicator are not. The meager effect size of technology on student learning is well below Hattie's (2008) "Zone of Desired Effects." Moreover, this impact has not changed in the past 50 years despite astonishing developments in technology in that time (Hattie, in Magana, 2017, p. i). Table 1 reports the results of these meta-analyses.

Table 1. Selected Meta-Analyses for the Effects of Technology on Student Achievement

	No. Metas.	No. Studies	No. Effects	d	Variance	Rank
Computer assisted instruction	40	2474	4251	0.47	0.06	94
CAI with elementary students	6	264	664	0.44	0.05	106
CAI with high school students	9	681	760	0.30	0.05	156
CAI with college students	11	2471	1732	0.42	0.06	115
One on one laptops	1	10	10	0.16	0.04	206
CAI in mathematics	18	865	1872	0.33	0.07	144
CAI in science	6	391	567	0.23		184
CAI in Reading/ Literacy	15	652	1183	0.29	0.10	162

CAI in writing	3	70	70	0.42	0.11	118
CAI in other subjects	3	96	103	0.55		67
CAI with learning needs students	4	114	144	0.57	0.05	57
CAI in small groups	3	193	616	0.21	0.08	195
Intelligent tutoring systems	3	231	231	0.48	0.02	89
Use of PowerPoint	1	12	16	0.26		176
Online, digital tools	7	288	357	0.29	0.04	160
CAI in distance education	2	28	28	0.01		235
Interactive video methods	6	372	3932	0.54	0.08	69

Clickers	2	81	183	0.22	0.09	189
Gaming/ simulations	18	797	984	0.35	0.06	136
Web based learning	3	136	136	0.18	0.12	203
	161	10226	17839	0.34	0.07	143

Source: J. Hattie, personal communication (2017).

It can be argued that while the "tell and practice" pedagogical model may have served students in the industrial and post-industrial ages, this model is insufficient to prepare the current generation of students for future success in the digital age. A reasonable inference can be made from the preponderance of evidence that simply digitizing teaching and learning practices of the past with current technologies has had a negligible impact on student achievement.

Pedagogies Enhanced by Technology

It is the idea of agilely adapting existing practices that have an established level of reliability to new, technology-rich contexts that may uncover pathways to better counsel the historically unhappy marriage of pedagogy and technology. An exciting new research trend suggests that one can expect a large effect on student learning when teachers intentionally wield educational technologies, not as ends unto themselves, but rather as means to enhance teaching and learning strategies that are correlated with moderate to large effect sizes (Haystead & Magana, 2013; Haystead & Marzano, 2009, 2010; Magana, 2016; Magana, 2017; Magana & Marzano, 2014).

Hattie (2008) observed that the impact of technology as a replacement for teachers is correlated with a low effect size of 0.30, but that when technology is used to enhance instructional and learning discussion between students and teachers, the observed impact increased to a moderate effect size of 0.45 (Hattie, 2008). In other words, instructional content which is delivered by a computer is likely to give rise to a 12 percentile point gain in student learning, but when that process is supplemented by dialogue between a teacher and student, the effect is likely to rise to a 17 percentile point gain in achievement (Magana & Marzano, 2014).

Moreover, Haystead and Marzano (2009) conducted a meta-analysis of 85 quasi-experimental treatment-control research studies focused on ascertaining the impact of interactive whiteboard and learner response technologies on student achievement. Haystead and Marzano (2009) concluded that:

> The average effect size for all 85 independent treatment/control studies was statistically significant ($p < .0001$). When corrected for attenuation, the percentile gain associated with the use of Promethean ActivClassroom is 17 percent (ES = .44). A reasonable inference is that the overall effect of a 17 percentile point gain is probably not a function of random factors that are specific to the independent treatment/control studies; rather, the 17 percentile point increase represents a real change in student learning. (p. 18)

These findings suggest that a greater, albeit moderate, impact can be realized when classroom teachers use educational technologies to supplement their instructional practices. While this is indeed cause for optimism, there is even more reason to hope for a happier matrimony between teaching and technology.

Recapping his findings on the impact of technology on student learning, Marzano (2014B) stated that “a good teacher with technology will usually outperform a good teacher without technology.” This is indeed cause for renewed hope as digitally rich learning environments may serve to enhance multisensory student interaction, knowledge expression and representation, multilateral dialogue, richer feedback systems, and individual and collective reflection. Compounding evidence suggests that substantive improvements in student learning can be attained with such shifts in instructional practices with technology (Hattie, 2008, 2012; Haystead & Magana, 2013; Haystead & Marzano, 2009, 2010; Magana, 2016; Magana & Marzano, 2014A).

Haystead & Marzano (2010) expanded upon their earlier investigation on the impact of interactive technologies on student achievement, effectively increasing the number of treatment-control studies from 85 to 131 and the sample size from 3,000 to just over 5,000 students. An additional phase was added, which involved viewing, analyzing, and coding videotapes of teachers using the interactive whiteboard and student response technologies in their classrooms (Haystead & Marzano, 2010). The intention of this additional phase of analysis was to “determine the behaviors that differentiated those teachers who obtained positive effects from [the treatment technology] from those who did not” (Haystead & Marzano, 2010, p. 69).

The combined average effect size of the interactive white board and student response technology on student achievement was determined to be moderate at 0.41 (Haystead & Marzano, 2010). However, very large effect sizes were observed for teachers whose instructional behaviors matched those previously identified by Marzano (2007) as having a high probability of positively impacting instructional quality. Haystead and Marzano (2010, p. 70) stated:

> Of the [14 Phase II variables], 6 exhibited correlations with correct effect size that were greater than .60, which would seem to indicate that substantial increases in student achievement would be predicted with improvements in teacher behavior with respect to chunking (Variable 10), scaffolding (Variable, 11), pacing [of instruction] (Variable 12), monitoring (Variable 13), clarity of instructional content displayed on an Interactive White Board (IWB) (Variable 14), and student response rate (Variable 16). The multiple correlation of .789 ($n = 99$, $p < .0001$) reported might suggest a strong effect on student achievement when the following conditions are met:
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> - New content is organized into small digestible bites designed with students’ background knowledge and needs in mind (chunking).
> - Chunks of new content follow a logical progression so that each chunk helps students understand the next (scaffolding).
> - The pace at which each chunk is addressed is adjusted as needed (i.e., slower, faster) to maintain high engagement and comprehension (pacing).

- Students’ ability to understand new content is consistently monitored (monitoring).
- [Interactive Whiteboard Technology, IWB] is utilized so that essential content is presented in a clear manner (clarity of IWB content).
- Questions are asked and addressed in a manner that would allow all students to have an opportunity to respond. Students’ answers should be continually examined for correctness and depth of understanding (student response rate).

The strategies Haystead & Marzano (2010) identified in the additional phase of their analysis (chunking, scaffolding, pacing, clarity of content, and student response rates) are correlated with a moderate to large effect size in and of themselves (Haystead & Marzano, 2010; Marzano, 2007). A new consideration that emerged from these findings is that large effect sizes might be likely when educational technologies are intentionally used to enhance the impact of highly reliable instructional strategies. Such an idea represents even greater cause for renewed optimism—and further investigation.

The author speculated that synthesizing and then applying these findings into an action research study (Lewin, 1947) would offer new insights into determining the impact that professional development focused on enhancing innovative instructional strategies with technology would have on student achievement. The professional development model developed was predicated upon simultaneously building teachers’ capacities with enhancing specific instructional strategies articulated in the Haystead and Marzano studies (2009; 2010) by integrating existing classroom technology tools—interactive white boards and student response devices (clickers) (Haystead & Magana, 2013).

The setting chosen for the action research study was a low-performing, highly diverse elementary school in Southern California and began in the 2009–2010 school year testing cycle (Haystead & Magana, 2013). The school predominantly served students living at or below the poverty line, with the majority of students either non-English speakers or speakers with limited English proficiency. Over 35% of the students were considered “highly mobile,” in that they moved their place of residence at least twice during the academic year (Haystead & Magana, 2013). The reasoning was that gains made by such disenfranchised learners would not only be generalizable to similar learning environments, but might also be generalizable to students in other learning environments who were not subjected to socioeconomic challenges known to have a deleterious impact on student achievement (Hattie 2008).

As reported in Haystead & Magana (2013), the school site had previously failed to make acceptable gains on the California Academic Performance Index (API) score, the statewide performance target for all six reporting cycles from the 2003–2004 academic year to the 2008–2009 academic year. In addition, the school’s API score fell below the median score of 100 schools serving a similar student population for five out of the six reporting cycles.

It is also important to note that prior to the start of the action research project, the school attained an API score of 769—which was 39 points below the statewide target growth score of 800. Happily, after the first year of implementing the professional development model, the school achieved an API score of 804 in the 2009–2010 reporting cycle, making adequate yearly progress for the first time. The school continued to make adequate growth gains for the next two years. After the third year of the action research project, the school achieved an API score of 841, which represents a cumulative three-year gain of 72 API points. By way of comparison, the school's three-year gain of API points for the reporting cycles 2003–2004 to 2005–2006 and 2006–2007 to 2008–2009 were 39 and 38 API points respectively.

From the findings of this action research project, Haystead and Magana (2013) concluded the following:

> The analysis of the school's Academic Performance Index (API) scores revealed that the school reached the statewide target Growth API score of 800 for the first time in 2010, during the first year of the action research [study]. In addition, the school's Growth API score was higher than the median value calculated from 100 schools with similar demographic characteristics. In the six-year period before the [study], the school's mean change in Base and Growth API scores (with standard deviation in parentheses) was 7.00 (27.71) compared with a mean change of 23.00 (13.11) during the three-year period of the action research [study]. Taken at face value, the difference between the mean change in Base and Growth API scores in each period suggests that the focused professional development had an influence on student achievement. (p. 20)

The reported cumulative growth is significant because it suggests that teachers' confidence and competence with both the instructional strategies and their uses of technology to enhance these strategies increased, resulting in improved student achievement. In a follow-up qualitative investigation, the school's teachers, principal, and a district administrator reported that significant increases in instructional quality, student engagement, and student achievement were the direct result of the professional development and classroom coaching they received on this new instructional model (Magana, 2016).

Clearly a negative trajectory had been disrupted by an innovative instructional model. When taken at face value, the compounding evidence from this line of inquiry may hold promise for other classrooms that might be considered digitally rich but innovatively poor. Disrupting the historically low impact of technology by synthesizing these compounding findings into a more precise and actionable framework was the impetus for developing the T3 Framework for Innovation in Education.

The T3 Framework for Innovation in Education

The trajectory of low-impact technology use in education is a wicked problem that has lasted for five decades (Hattie, 2017). A decidedly challenging implication of this wicked problem is this: if overlaying digital teaching and learning tools on “tell and practice” pedagogy remains steadfast, then one can expect the impact of new and emerging technologies—such as virtual reality, artificial intelligence, and the Internet of Things—to be, on average, about 0.34 for the next 50 years or more (Hattie, in Magana, 2017, p. i).

Teaching and learning are quite complex because of the profound challenges associated with the nature of generating and assessing knowledge and understanding. Adding educational technology tools has arguably added complexity to already complex processes in school systems. Frameworks help to ground complex phenomena into understandable contexts in order to facilitate fruitful meaning-making (Fairhurst, 2011). But have frameworks helped to improve the impact of technology on student achievement?

Perhaps the most dominant framework that is used to guide technology integration in educational settings is Technological, Pedagogical, and Content Knowledge (TPACK) (Mishra & Koehler, 1998). TPACK was developed in the late 1990s and helped to elevate the importance of teachers’ technological knowledge to that of pedagogical and content knowledge. However, what has been an ongoing challenge is that the TPACK framework does not provide explicit guidance as to how educators might actually achieve that technological knowledge. TPACK provides goals but no clear pathway towards those goals. This is a shortcoming of the TPACK model, and has led to misapprehension, misapplication, and inaction. Unfortunately, other models have arisen that suffer the same weakness as TPACK, specifically undefined goals with no clear pathways for achieving them.

Another popular framework for integrating technology into teaching and learning is the Substitution, Augmentation, Modification, and Redefinition (SAMR) model (Puentedura, 2009), referring to four stages of technology use. The SAMR model is a hierarchical scale which describes the extent to which the use of technology changes the nature of tasks. For example, technology serves as a replacement for analog tools in the Substitution phase, yet adds functional enhancements in the Augmentation phase. Technology further provides opportunities to modify tasks in the Modification phase and allows for a redefinition of tasks in the final phase.

Unlike the TPACK model, the SAMR model is not underpinned by any educational research. This is a glaring weakness. Another weakness is the ambiguity associated with the ordinal descriptions of each stage in the SAMR model. This has led to a great deal of equivocation over interpreting the precise meaning of each phase. Furthermore, the SAMR model does not provide any strategies that can be enacted by either teachers or students, which makes this model exceedingly difficult to implement, observe, or measure.

The first step towards building the collective efficacy of any organization is to embrace a common language for innovation (Magana, 2018). Disrupting the current narrative about the use of educational technologies requires a more precise and actionable language and set of ideas to discuss, enact, and evaluate high-impact uses of digital tools in education. The primary objective of *Disruptive Classroom Technologies: A Framework for Innovation in Education* (Magana, 2017) is to provide learning systems with a common and actionable language for implementing and measuring the impact of innovative teaching and learning practices with readily available technologies). T3 Framework for innovation in education is a synthesis of four decades of research on solving the wicked problem of low-impact technology in schools (see Figure 1). The T3 Framework provides a much-needed pathway forward that is both grounded in sound research and theory, and promotes educational uses of technology that reliably accelerate student learning.

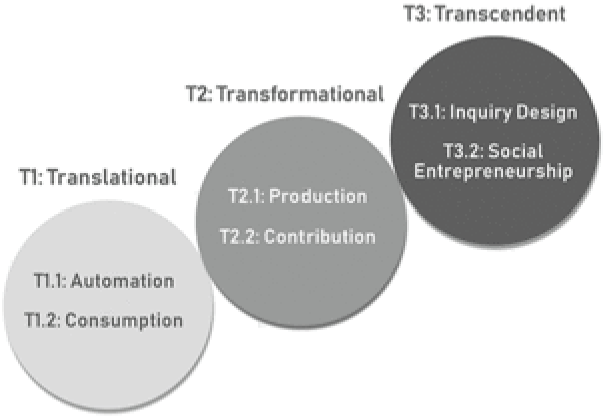

Figure 1. The T3 framework for innovation.

Source: *Disruptive Classroom Technologies* (Magana, 2017).

The T3 Framework increments the use of technology in the realm of teaching and learning into three hierarchical domains: Translational, Transformational, and Transcendent (Magana, 2017). Translational technology uses reflect the most common ways that digital tools are used in schools. Translating tasks from an analog to a digital form should be considered an entry-level of technology use which adds some value in terms of increasing efficiency, accuracy, and time savings. The two elements in the translational stage of technology are T1.1) Automation and T1.2) Consumption.

The teaching and learning tasks associated with the element of automation involve saving time, improving efficiencies, and reducing errors by automating administrative and teaching duties. These include communicating, budgeting, grading, attendance taking, and testing. Those tasks associated with the element of consumption include teachers and students accessing and consuming digital content knowledge and information from online sources or other electronic media. These two elements are illustrative of a necessary first stage, but all too often school systems make the mistake of stopping there. The impact of the T1: Translational stage of technology use—that is, simply automating teaching and learning tasks, or consuming content knowledge and information through digital tools—has been historically low (Hattie, 2008, 2012, 2017).

Transformational technology uses, on the other hand, enact significant changes in the learning tasks and substantive changes in the students performing those tasks. This domain includes strategies for students to embrace a “mastery mindset” through developing mastery goals and then mindfully monitoring the impact of their effort and progress towards those goals. Moreover, affording students multiple opportunities to use digital tools to represent what they know, what they can do, and to make their thinking explicit, so they can contribute to others’ learning, are illustrative of transformational technology uses.

Rather than placing a greater burden on teachers, advancing from the T1) Translational phase of technology use to the T2) Transformational stage engenders shifting the loci of learning experiences from teachers to students. Transformational technology use in education “reflects the intentional application of digital technologies to unleash students’ learning expertise, in ways not possible without technology, to achieve ever higher levels of knowledge and mastery” (Magana, 2017, p. 39).

The two elements of the transformational stage of technology use are: T2.1) Production and T2.2) Contribution. In the production stage, students leverage technologies to produce mastery goals to help them regulate their effort, progress, and emotions as they progress towards learning intentions. Additionally, at this stage, students produce digital representations of their declarative and procedural knowledge, and make their thinking pathways explicit to themselves and their teachers. In the contribution stage, students use digital tools to design, create, share, and scale digital knowledge products with the purpose of teaching others what they know. This is inherently transformational because the learners are substantively changed from learners who consume and recite content knowledge to contributors who produce knowledge artifacts designed to elicit from others an understanding of their newly acquired knowledge. This shift also supports students in the important process of transferring their knowledge into unique and useful contexts (Hattie & Donoghue, 2016).

Thus, in addition to enacting substantive growth in student cognizance, transcendent technology uses push past the boundaries of prior experiences and expectations for education. The two stages of transcendent technology use are T3.1) Inquiry Design, and, T3.2) Social Entrepreneurship. The strategies in the inquiry design include students using digital tools to first identify, and then investigate, hypothesize, and design resolutions to wicked problems that matter to them. The strategies in the social entrepreneurship stage guide students to intentionally and contextually wield new and emerging software coding and digital tool-building environments and communications platforms to iteratively generate and scale more robust digital solutions to the wicked problems that matter to them. This represents an entirely new domain of strategies that is only possible when students mindfully wield digital and cloud-based production technologies in this manner.

Transcendent technology use begins with student passion and concludes with students engaging in designing original lines of inquiry (Gray, 2014) and applying social entrepreneurship strategies to solve wicked problems that matter to them. This not only affords students opportunities to explore, interpret, discuss, and critically address problems that are important to them, but offers pathways for students to become leaders for action who make a significant contribution to their local and extended communities (Magana, Henly, Murphy, Rayl, & Travis, 1996).

Compounding evidence suggests that implementing the strategies in the T3 Framework, with reasonable fidelity, will likely increase the impact of digital technologies to unlock students' limitless capacities for self-regulation, self-determination, and contributive learning (Haystead & Marzano, 2009, 2010; Haystead & Magana, 2013; Magana, 2016; Magana, 2017). A reasonable inference can be made that such capacities will arguably serve to better prepare today's students, not only for current learning challenges, but for the future learning challenges they will encounter.

In order to maintain relevance in the modern digital era, learning systems can no longer rely on evidence-free opinions to best understand how technologies will accelerate student achievement. Such a reliance will only result in more learning environments that are digitally rich, but innovatively poor. A reasonable predication is that, using the guidance provided by the T3 Framework, learning systems can build rather than rely upon pedagogies of the past to generate collective efficacy in our learning systems. Doing so will not only disrupt the historic pattern of low technology use in education, but will serve to unlock students' potential, passion, and purpose for limitless learning. Transcending the historic limitations of organized educational systems is an idea worth pursuing through the lens of continued investigation and research.

Future Research Directions and Inquiry Opportunities

The Greek philosopher Heraclitus astutely observed that one must embrace a constant state of becoming in order to reach the optimal realization of our human potential. A reasonable implication of this philosophy implies that transcending the known limits in any endeavor is not a final destination but a process of continuous growth and mastery. Transcending the historic expectations and limitations of organized educational systems is a function of harnessing new and emerging digital tools while continuously seeking systemic feedback to help determine the impact on student learning and achievement.

As teaching and learning is as much an art as a science (Marzano, 2007), educational systems would benefit from a road map with crystal clear goals, and just enough mileposts to allow creativity to flourish over prescriptive, lock-step compliance. This is perhaps one of the most valuable attributes of the T3 Framework for innovation in education: it is a precise, yet tempered guide, designed to both stimulate the realization and determine the impact of collective efficacy, through agile and adaptive implementation of the elements and strategies in the framework.

Such a philosophical approach also demands a shift in thinking from professional development towards organizational development. Educators have been receiving professional development focused on building technology skills for four decades, with alarmingly little learning impact to show for the effort. A key factor contributing to the disappointing results of teacher training on technology rests with knowledge transfer (Hattie & Donoghue, 2016). While much of the research literature on teacher training focuses on skill acquisition, few studies have actually measured transfer effects from the training room to the classroom (Joyce & Showers, 1988). Helping teachers transfer newly gained skills into their instructional practices holds great promise for improving instructional quality and student achievement. Joyce and Showers (1988) report:

> In studies that have asked the transfer question (e.g., did participants use new skills in the classroom, did they use them appropriately, did they integrate new skills with existing repertoire, was there long-term retention of the products of training), several findings emerge. First, the gradual addition of training elements does not appear to impact transfer noticeably (ES [effect size] of .00 for information or theory; theory plus demonstration; theory, demonstration and feedback; ES of .39 for theory, demonstration, practice and feedback). However, a large and dramatic increase in transfer of training—ES 1.68—occurs when in-class coaching is added to an initial training experience comprised of theory explanation, demonstration and practice with feedback. (pp. 71–72)

These findings strongly suggest how important it is for organizations to leverage system-wide support, leadership, and ongoing instructional coaching during the implementation phase. Implementing evidence-based practices is a team sport. This shift is necessary to ensure that all teachers in a learning system are able to confidently and competently transfer new evidence-based knowledge and strategies into their classroom practices (Magana, 2016).

It is also important to continuously evaluate the impact of implementing evidence-based methods. This is particularly true when it comes to building collective efficacy with educational technology use. Learning systems would benefit from using the T3 Framework for innovation to guide this process. The first step is to assess the current level of technology use within the three stages of the T3 Framework: T1: Translational Technology Use, T2: Transformational Technology Use, and T3: Transcendent Technology Use.

It would also be helpful for teachers to use a mastery scale to reflect on their current levels of technology use on the T3 Framework. In order to be actionable, mastery scales should be clear, precise, and manageable. Adding too many stages makes such scales less usable as a tool for reflection in action during instruction. It is possible to agilely reflect upon individual efficacy using a simple scale such as 1) Beginning, 2) Developing, and 3) Mastering. Using this nominal scale in aggregate, teachers across whole schools, districts, regions, states, or nations can more accurately self-assess their current use of technology, providing a clearer picture of the here and now (see Table 2).

With these incremental stages clearly in mind, educators can then more accurately establish meaningful growth goals and track their progress towards mastery within and between the elements in the T3 Framework. This evaluation process would ideally include instructional coaches and building leaders to evaluate impact, and provide sufficient guidance and resources as needed to ensure continuous growth towards mastery. Such a systemic process would serve to both catalyze organizational growth while strengthening the argument of causality between teachers' mastery of transformational and transcendent teaching and students' mastery of current and future learning.

Table 2. Magana Mastery Scale for Teachers

Mastery Score	**Indicator**
3	Mastering: Agile, adaptive use of digital tools to enhance teaching and learning tasks that demonstrates impact mindfulness and is free from critical errors or oversights.
2	Developing: Nearing agile, adaptive use of digital tools to enhance teaching and learning tasks that demonstrates some impact monitoring and some critical errors or oversights.
1	Beginning: Not yet nearing agile, adaptive use of digital tools to enhance teaching and learning tasks that demonstrates little or no impact monitoring and critical errors or oversights.

Source: Disruptive Classroom Technologies (Magana, 2017).

If evidence-based practices matter, then implementing evidence-based practices matters more. If this is true, then evaluating the impact from implementing evidence-based practices masters most. Therein lies a call to action for other education researchers and practitioners to boldly follow this line of inquiry, and continue to expose the speculative ideas contained in this article to the hazards of refutation. It is important to heed Karl Popper's (1968) call to action and take part in the scientific game in order to hazard the prize of understanding the conditions that make the marriage between pedagogy and technology more harmonious.

Continued systematic investigation will bring greater clarity of impact that the transformational and transcendent strategies in the T3 Framework have on student learning and achievement. Over time, enough evidence may be gathered to enact rigorous meta-analysis in order to generate effect sizes for each these strategies. Over a longer period of time, the preponderance of evidence provided by such meta-analytical examination may help codify the elements and strategies of the T3 Framework into a new third millennial epistemology which transcends the historical purposes—and limitations—of organized educational systems.

The emerging evidence base suggests that it is possible to transcend the epidemic of low-impact technology by disrupting the current trajectory with the innovative teaching and learning strategies in the T3 Framework. Articulating an epistemology that seamlessly integrates new pedagogies with new and emerging educational technologies will not only help guide this work at hand, but in the aggregate will keep moving the needle of technology impact forward now, and possibly well into the future. Collectively embracing a disruptively innovative mindset will help educational systems realize their potential for collective efficacy—and model that process for their students. The T3 Framework and accompanying mastery scales represent such a disruptive innovation. This model was intentionally designed to aid in the process of masterfully choreographing the symbiosis of modern teaching and learning processes and digital tool systems to ensure that today’s students are fully prepared to masterfully address whatever challenges the present or future may hold for them. Arguably, that matters most of all.

Links to Digital Materials

Webinar: **An Introduction to the T3 Framework for Innovation**.

Magana Education.

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