EDUCATION IN CONTEXT OF STUDENT-ACCESSED, DIGITAL AND APPLIED TECHNOLOGY

by

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Table of Contents

Preface

I have been involved in parochial education for most of my career, both as a teacher and as a headmaster. My professional career has spanned three decades that has witnessed astonishing technological advancement in the classroom. In the 1980's – a lifetime ago when I was in graduate school – computers were just becoming affordable for students. My friends and I liked the early Apple machines over Microsoft because they could display and print Greek and Hebrew characters, two languages I was studying at the time. How far we've come.

As an adult I've watched computer technology continue its advance down into the K-12 setting. As a teacher who relies on PowerPoint, shows an occasional film, and utilizes on-line resources I am a fan of the tools and gadgets available today. As a headmaster of a school of nearly 500 students, however, I have developed a healthy skepticism for freewheeling use of computers in the classroom. I have watched colleagues in the public and private sector chase technology in response to public expectations, spend vast amounts of money, make implied promises to their constituencies, and return about the same test scores year after year.

One local public elementary school in my town ran an ad in the newspaper that shouted, "Laptops for all third graders." No other claims were made, but the assumption was that this was unquestionably a good thing. I wondered to myself what third graders, who should be learning cursive handwriting, would do with such a gadget. After all, a laptop by itself has more computing power than we used to send men to the moon. That was the moment that this project was born.

The idea for this paper was reinforced when our local public high school began handing out Chrome Books to all its freshmen students. The machine came with a policy of one free replacement for loss or damage, a policy which immediately created a supply of "lightly used" computers on Craigslist. I was not sure who wrote that policy, but I was pretty certain that the school board had overlooked this unintended consequence. I wondered if our tax money was being spent with intention, and if teachers were in-serviced extensively enough to take advantage of the technology so freely supplied. After all, I've been teaching children to read successfully for two decades with a piece of paper and a pencil, at a cost of about thirty-five cents in materials per child.

I operate a fairly "low-tech" school, I manage budgets carefully, and I don't have the luxury of providing to my faculty every cutting edge gadget. Sure we have computers, short-throw projectors, internet connections and the rest, but primarily the school maintains a classical curriculum, rooted in the liberal arts, and works within the Anglican tradition. We read and write; then we read and write some more. Remarkably, we have enjoyed the highest average SAT scores in the city for 15 years running, 250 points above the national average. We produce more National Merit Scholars per capita than any school from Southwest VA to Staunton, and we maintain an astonishingly high pass rate (3+) on AP exams, often without teaching AP curriculum. All of our graduates matriculate into colleges or universities, most earning significant merit scholarships, even though we don't bill ourselves as a prep school. How do we do it? The answer involves very little technology. One of my graduates reflected on his freshman experience in his engineering program at a notable university, "I was a little behind on the computer programming when I arrived; on the other hand, none of my classmates had ever read Homer."

This project was motivated therefore to find the connection between technologies in the classroom, which I define as any medium that is student-accessible, digital, or applied technology (SADAT for short), whether it is used actively or passively by the learner. I divided the paper into three sections. In Part 1 I compare traditional education with the 20th century challenges posed by John Dewey's Progressivism. I felt that this was important because technology tends to retro-inform any curriculum, and I wanted to be clear about the designs of the competing worldviews and their assumptions.

Second, I had to look at the data. In Part II of the project I survey two key studies and one meta-study for more scientific conclusions about the effects of computers in the classroom. The results are mixed, and in my judgment not compelling enough to justify the tech race in which we find ourselves.

Third, I wanted to answer the question raised by tech advocates, some of whom seem to believe that computers transform the way students *learn*, and are thus indispensable. What I show in Part III is that SADAT is deployed routinely within the constructs of existing theories of cognition, and does not as yet represent a new way of knowing or learning. Learning is hard work and ultimately requires an engaged learner. As Richard Clark quips "Grocery trucks have little impact on our nutrition. They merely deliver food. That is how technology works."

Thus, if I have achieved my goal, I show that the hard work of educating children is often supported by tools offered by SADAT. Nonetheless, it is no substitute for the efforts of the gifted teacher.

Introduction

This paper investigates the question of whether student-accessible, digital, or applied technology (SADAT), fulfills its promise to revolutionize the learning process in traditional schools. SADAT is a broad term that includes any technology in the classroom or home to which students have direct access, especially, but not limited to digital technology, including educational software, internet access and other devices that communicate with the internet. It challenges the popular assumption that technology in almost any form is an unqualified good, and that it should unquestionably be deployed in the classroom context. So strong is this popular notion that policy makers, superintendents, and teachers feel compelled to chase technology without clear-cut policy guidelines or a clear understanding of how technology is to be used. Often, it is simply assumed that student achievement is positively affected by the deployment of technology, or that computer technology is essential to learning.

Policy-makers, administrators, and instructors should not accept as axiomatic that the use of SADAT in the classroom will create a new set of positive conditions for learning. Rather, we are cautioned by Christina Erneling to recognize that much "technology is introduced by people *without* direct experience of classroom conditions…who often want to supplement and even *reduce* the role of the teacher (emphasis mine)" (Erneling 44) This paper also examines her claim that technology is deployed without sufficient consideration for the educational philosophies and philosophies of learning.

Limits of the discussion

Public K-12 education in the United States necessarily serves a broad spectrum of students from the college-bound student at one end of the spectrum to physically and/or mentally disabled learners on the other. Determining the objectives and the programmatic needs of students anywhere on such a broad scale is largely mandated by state and federal law for schools in the public sector, and implemented with some autonomy by local jurisdictions. Locally elected school boards have latitude in making the details of their programs correspond to the expectations of their constituencies, moderated by the relative wealth of their populations, and by the revenues of their tax bases. How well these programs are delivered to students is not of interest to this project, but the disparate groups served are relevant insofar as the deployment of technology may or may not apply evenly to classrooms in every group.

This discussion is limited to the educational pursuits of students who function in a traditional classroom without significant interventions, accommodations, or other special conditions. We refer to students in these schools as traditional learners. Since the application of SADAT for non-traditional learners may be remarkably different from the traditional classroom, schools that serve non-traditional learners – even programs within traditional schools – will not be considered. It is important to note that even among schools arranged to serve traditional learners, there are vast design differences and thus, very different expectations for outcomes. This variation is only partially explained under the rubrics of public vs. private, faith-based vs. secular, and liberal vs. vocational approaches. This requires us to appreciate differences in philosophy, and to acknowledge the difficulty created by the lack of a unified working definition of education. Even if we acknowledge differences in aims and desired outcomes, however, we question the assumption that technology can be relied upon to produce measureable advances in learning.

The paper is divided into three sections. First, I compare traditional (classical, liberal) education to the Progressive theories of John Dewey. Each of these pursues education with a set of assumptions which make them more or less receptive to the challenges of technology in a digital age. More importantly each possesses a vision of education that is fundamentally different at a philosophical level. Recognizing this helps us see that classroom technology may further their respective aims in different ways.

Second, I offer selective data that assesses the effectiveness of technology since 1998. The data is voluminous on the one hand; thus, my choices are relatively limited. On the other hand, the data picture is remarkably uneven due to the variables that make research quite difficult, with the result that extensive citation of studies tends to confirm the muddiness of the whole picture.

Third, I propose that while technology appears to be quite revolutionary, it nevertheless tends to find deployment in the service of existing educational theories. Although SADAT has sparked debate about brain development and cognition, it has not yet led to, or put in service of, a new theory of cognitive development. I explore two leading types of theories, the Behaviorism traceable to B.F. Skinner and the Constructionist views of Jean Piaget as modified by subsequent theorists.

Part One – Traditional and Progressive Education

Educational Contexts

Education has been construed historically to revolve around two broad polar modalities. These poles, or perspectives, should not necessarily be understood as judgments of value; rather, they reflect two different perspectives, one liberal and the other utilitarian, productive, or what we might term, vocational. By liberal education we contemplate a curriculum not merely for the traditional learner, but a curriculum that descends from the traditional liberal arts paradigm. By vocational education we refer to a curriculum of productive arts that, while offering some exposure to the liberal arts, will by design, foster skill for utilitarian purposes. Successful outcomes in this mode of education include specific job skills or job training, and is not typically offered to contemporary students below the high school level. This is accomplished through a curriculum designed to impart specific skills that approach the immediate demands of the market or "work-place" readiness.

The perspective of this paper is skewed toward the liberal arts tradition, a primary and secondary education that provides a student with a broad and necessarily basic facility across the disciplines of language (both in the mother tongue and at least one foreign) and literature, mathematics (computation and reasoning), music, logic, writing and speaking (rhetoric), philosophy and religion. There are notable omissions from this list, history and science to name two, that might be included in a modern, liberal arts syllabus.

The Liberal Arts Tradition

Both models of education are valid, of course. The former, historically obtained through tutors or expensive cathedral schools, was afforded those with the means to pay for it, and typically – but not always – reserved to boys; the latter, encompassing skills from agriculture to welding, has been historically acquired through apprenticeship. The most important differences in approach, however, do not lie in the classes of persons that had access to them. The aims of liberal and vocational models are quite different in themselves.

The liberal arts tradition dates to the ancient Greeks and to a lesser extent, the Romans, who advanced the idea of the trivium: grammar, dialectic (logic) and rhetoric. The full flower of their efforts, however, did not blossom until the early centuries of the Christian Era. By the fifth century forward the seven branches of the liberal arts had been canonized by Martianus Capella. His book, The Marriage of Philology and Mercury, was widely circulated and studied through the middle ages as a touchstone of educational philosophy.

After Capella the disciplines of the trivium – grammar, dialectic, and rhetoric – took their place alongside those of the quadrivium: music, mathematics, astronomy and geometry. The former were seen as preparatory disciplines, but because they were understood as modes of learning, they did not merely *preceed* the disciplines of the quadrivium in a rigid sequence. Rather, they were considered as tools used simultaneously in the assimilation of knowledge at all levels. Similarly, the disciplines of the quadrivium, which at first glance appear rather limited to the contemporary mind, do not exclude other "subjects;" rather they include algebra, calculus, and theory of equations (Joseph 3-9). Moreover the sciences of physics, chemistry, and music theory – not applied or performative music – should be understood as subcategories of number theory because they pertain to "scientific measurements of discrete quantities" (8).

Put simply, the disciplines of the quadrivium fall roughly into two categories: 1) issues that pertain to multitude such as mathematics and music; and 2) issues that pertain to magnitude such as astronomy (macro) and geometry (micro). Understood this way, "education is the highest of arts in the sense that it imposes forms…not on matter…but on mind" (7-8). To put a finer point on it, the disciplines of the Trivium pertain to the mind, while the disciplines of the Quadrivium pertain to matter. The "three ways" of the Trivium and the "four ways" of the Quadrivium combine to form the seven liberal arts, which, for most of the history of the West, comprised the curriculum.

The history of the liberal arts is well documented, and need not be fully rehearsed here. It will suffice to note that the seven liberal arts represented the successful cataloging of human knowledge into branches of learning while maintaining a coherent field of knowledge. Equally important, the Trivium – grammar, dialectic and rhetoric – is "in itself a tool or a skill" which provided the technique to acquire that knowledge (7). The liberal arts thus describe not only the content of human learning, that is, what might be known, but also the *methods* or *modalities* by which learning was to take place.

Modalities of the Classical Tradition

The modalities of grammar, dialectic and rehetoric which constitute the Trivium are not only "subjects," but modes of teaching. Dorothy L. Sayers overstates the case somewhat in her *The Lost Tools of Learning*, a speech she delivered at Oxford in 1947: "Now the first thing we notice is that two of these "subjects" are not what we should call "subjects" at all: they are only methods of dealing with subjects." (Sayers). Classical learning refers to content, but a content into which is embedded an inherent pedagogy, a technique, for aquiring, testing, and articulating information. For Sayers, classical pedagogy is therefore implies an implicit theory of instruction rooted in a long history of non-scientific observation of how children learn. Although Sayers herself admitted that she was "unenlightened" on child psychology, nevertheless she was probably the first to construe the Trivium as a form of developmental stage-theory in a manner that appears to be remarkably congruent with that of Jean Piaget, which I discuss below. What I refer to as "modes" of learning in the grammar, dialectic and rhetoric, Sayers termed as "stages" of learning which she called the "poll-parrot, the pert, and the poetic" (Sayers). In doing so she psychologized the Trivium by matching the modes of grammar, dialectic and rhetoric to stages of child development (Littlejohn & Evans 35).

Grammar Mode: Acquisition of Recorded Fact

The grammar mode first involves the acquisition of language, which includes reading, writing and the function of words. Human beings may not be the only living organisms that communicate, but it is likely that humans are unique in that we use words as symbols of reality. "Only human beings have the power of intellectual abstraction; therefore, only human beings can form a general or universal concept" (Joseph 23). When a young student encounters words, his first task is to decode them so that they are apprehended in the process we call reading. Immediately words are the blocks of thought – the things we think with. The student can learn that any word bears a relationship to reality, which Aristotle classified into ten categories of being: substance, quantity, quality, relation, action, passion, duration (time), location, posture, and habiliment. Words, then, structure our understanding of reality, and thus, grammatical skills are paramount in classical pedagogy because through them a student comes to understand the kinds of relationships that are possible.

Second, the grammar mode not only implies learning a language, but refers to the process of fact acquisition. Viewed this way, we can talk about about Latin grammar, or the grammar of any language, but we can extend the method to contemplate other subjects, such as a "grammar" of mathematics, of art, or of history. The way a student approaches a subject begins in the grammatical mode, which Sayers referred to as a "tool of learning." Appealing to the innate mental powers of young children, she advocated for example that Latin should not only be taught, but that it should be taught *early*, because learning "*amo, amas, amat*" presents no more difficulty to a child than learning "eenie, meeny, miny, mo." Learning an inflected language such as Latin introduces a student to word relationships in a form-based, rule-based system. Sayers referred to this as the "poll-parrot" stage of learning, which relied heavily upon imitation, repetition and memory.

Moreover, a student who could translate rudimentary Latin by middle school would be engaging in a foreign language, not necessarily for the purpose of speaking, but for the purpose of listening. In translation he could hear voices from across the ages, engaging in the act of translation, which is to engage in the act of thought itself. Language acquisition, coupled with the pedegogies of observation and memory, summarize the grammatical method, which is the way a student acquires recorded fact, and is introduced to ultimate reality.

The Dialectic: Testing Recorded Fact

Early classical pedagogy relies heavily on the collection of materials: language, poetry, legends, myth, proverbs, fables, etc., but when we move to the dialectic mode we include disputation and logic. Aristotle lit the way, of course, with the first formal text. In doing so he "mapped" human speech, showing how language is rational and expresses rational contact with reality. Thus, in classical pedagogy the skill required to form an argument, write an essay, and above all, spot unsubstantiated inference, is expected of every student. If the grammatical mode is a tool for aquiring recorded fact, logic is the tool for testing the validity of facts. Therefore, just as every subject has its own "grammar," so also does it have its own dialectic. Arithmetic is highly grammatical; algebra is highly dialectical.

Sayers maintained however, that the dialectic *stage* corresponded more or less to the middle school child. She referred to it as the "pert" stage, "which…is only too familiar to all who have to do with children: it is characterized by contradicting, answering-back, liking to 'catch people out' (especially one's elders) and the propounding of conundrums (especially the kind with a nasty verbal catch in them). Its nuisance-value is extremely high. It usually sets in about the eighth grade" (Sayers).

Sayers thought that, if one were to teach to the grain, formal logic should be introduced at precisely the time young students demonstrated a love of argument. Any parent of middle school children will identify with her observation that "…it will doubtless be objected that to encourage young persons at the pert age to browbeat, correct, and argue with their leaders will render them perfectly intolerable. My answer is that children of that age are intolerable anyhow, and that their natural argumentativeness may just as well be channeled to good purpose as allowed to run away into the sands" (Sayers).

Rhetoric: Clear-minded Expression

Finally, the scope of classical pedagogy extends to the mode of rhetoric, which Aristotle defined as the faculty of observing in any given case the available means of persuasion.   Relying upon the grammatical mode, and closely tied to the dialectic, rhetoric represented the culmination of knowledge, analysis, and articulation – written or spoken. Aristotle's catalogue of Common Topics furnishes us with the kinds of argumentation appropriate to any one of three types of the rhetoric – epideictic, forensic, or deliberative – and still stands as the touchstone of the curriculum, even for the modern student. Thus, grammar and dialectic contemplate acquisition and testing of recorded fact, while rhetoric contemplated the expression of fact in various contexts.

Liberal education is distinguished from utilitarian or vocational education insofar as it is "intransitive" (Joseph 4). That is to say, the learner is the thing shaped in the process of education. In contrast, a vocational education trains the learner in a skill, perhaps a very high skill, in which the student produces a service or a good external to himself. Carpentry, plumbing, welding, and even law and medicine can be classed as utilitarian training because they represent skills that can be aquired and conveyed to others. The “product” of a liberal education is neither a thing or good that can be priced as a commodity and conveyed in the market. Rather, the product of a liberal education is the student himself.

Liberal education is therefore concerned with bringing the student into contact with the forms of reality be they mathematical, philosophical, theological, or metaphysical, etc. In fact, following both Plato and Aristotle, “the first premise of classical education is that there is an “Ideal Type” toward which education aspires. “The Ideal Type’s ancient, prescriptive pattern of truth – which served Christian and Jew, Roman and Greek – remain the most durable and the most comprehensive” (Hicks 8). In spite of variations and outright differences, the classical tradition in pagan and Christian contexts shared a commitment to normative aspects of knowledge as opposed to operational aspects, emphasizing and advocating a concern for those things that *ought* to be done, as opposed to the modern notion of what *can* be done (11). In other words, the arc of the educational endeavor was bent toward the formation of the person, rather than to the cultivation of marketable skill.

Normative knowledge, collected over time, forms a tradition, and a tradition over time undergirds a civilization. Educators in the Western tradition saw their task therefore as transmitting that culture. As we shall point out below, the strongest twentieth century challenge to the liberal arts tradition was Progressivism, and its objections may be understood as a reaction both to the norms of the Western tradition, but also to the pedagogies implicit in the Trivium.

Public education in the United States until the late nineteenth century was largely informed by the liberal arts paradigm. Even the regimen of the utilitarian pursuits took its definition from its larger context of the liberal arts. It is important to note, however, that both liberal and utilitarian streams historically remain part of this tradition, and should not be falsely dichotemized. In other words, historically speaking, the modes of education that do not by strict definition meet the standard of the liberal, medieval syllabus, nevertheless should be distinguished from the later pragmatic and Progressive movements that displaced them in the twentieth century.

This is evident from the disciplines that were historically included in the catalog of utilitarian arts, a point that comes into clarity if we offer sharper defintions. Vocational education is concerned with what the Greeks called *techne* (τεκνη), which suggests the acquisition of knowledge or skill (technology) to develop power to act upon matter, to exert change in the natural order, to create or control, or to produce or to modify. The fine arts, which originially included such disciplines as architecture, were of this latter class, because they pursued outcomes of an external nature or effects upon matter; that is, the end product was considered an external good, albeit one that required a high degree of skill. On the one hand, music *theory*, in the most stringent of liberal studies, would be studied as a sister to mathematics, and thus would take its place in the liberal curriculum; on the other hand, *performative* musical arts would be regarded as an external endeavor and would thus be referred to the utilitarian arts (Joseph 8). Such distinctions would likely fail to gain much traction from a contemporary point of view, which points to the necessity of further distinctions which arise in the late nineteenth century and educational reform movements.

It is easy to anticipate that these two educational perspectives, unfolding over the course of centuries would posture themselves differently in their receptivity to technology proposed in the educational setting. The advancement of technology, say, from scroll to codex, or from handwritten manuscript to moveable type, advanced the educational experience in every way. It tended to make learning more broadly available and efficient, just as advancement in tools and methods of manufacturing increased the output of labor. So each educational perspective would have been receptive to such technology. The difference to which we refer in this paper has less to do with access to information made possible by technological advances, and more to do with student accessible technology as a primary tool of learning.

Educational Modalities

At this point we have divided education into two broad polarities, the liberal arts and the utilitarian arts. We do so in respect to centuries of tradition in which this division serves to describe the historical reality until the mid-nineteenth century. We also recognize that contemporary education (c. 1890 – present) clearly defies this simplicity. Thus, while we prefer the term *classical* education, we can accept the simplistic label of *traditional* education, a term which tends to compress complexity and blur the historical distinctions between them. Nevertheless, from the standpoint and purposes of educational theory in the twentieth century, these dinstinctions are largely irrelevant.

It is would be an error to suggest that pure distinctions between liberal and utilitarian arts as described above created parallel tracks which give way to two modes of education in the modern world. We in no way suggest that classical, liberal education follows an arc that bends only toward the pursuit of humane letters and theoretical abstractions, while the productive arts bend toward modern vocational disciplines. The implication of such an error would be to conclude that the productive arts present a receptivity to technology in the contemporary classroom, or shop, in a way that liberal, traditional education might spurn. Indeed, a liberal arts education is advanced by the resources technology can provide, just as a vocational education can benefit from advances in technology, but this is not the precise point of this paper.

Twentieth Century Challenges

By the end of the 19th century, traditional education in the classical tradition was under pressure on a number of fronts. In the American, democratic context, classical education was not only perceived as elitist, but it is not even clear that classical education had an authentic expression in academia, or was guided by demonstrated scholarship. The mixed review is shared by E. Christian Kopff who concludes that "America does have a tradition of classical scholarship, but not an overly impressive one" (Kopff 102). Nevertheless, it is true that the classical traditions influenced politics, culture, the media, and it persisted in American schools – at least as evidenced by the presense of Greek and Latin – through the mid-20th century.

The critics of classical, traditional education objected not only to the curricular content but to the *telos* of the pedagogy itself. The critics were many, but by far the most important and influential was John Dewey. Writing at the very end of the 19th century and into the early twentieth century, Dewey's criticism of the liberal arts tradition is fairly complicated. His objections to traditional education display objections to approach, to content, and most acutely to purposes of education and to pedagogy itself.

Dewey's effort in <u>Experience and Education</u> amounted to a blunt repudiation of traditional education, which "consists of bodies of information and of skills that have been worked out in the past…[and the] chief business of the school is to transmit them to the new generation. Since the subject-matter as well as standards of proper conduct are handed down from the past, the attitude of pupils must…be one of docility, receptivity and obedience" (Ratner, 654). Further, because the content in such an educational model is so "adult," the student is sacrificed in the process because the development of the student is not suitable to the content, the pedagogy or the behavior required to learn in that context.

This mode is suppressive of individuality and creativity, but most importantly, it is *contrary to how students learn*. Traditional education – pre-packaged, static, removed from the student's experience, etc. – is "opposed [to] acquaintance with a changing world" (657). Dewey lived during immense technological (industrial) change and could anticipate, if not foresee, the present technical age. Accordingly, his motivations did not lie in advocacy for the implementation of particular technologies or universal access to them. He fully recognized that in rejecting the traditional paradigm, he was obligated to advocate for a fully developed replacement. Dewey was clear that it was not enough to merely repudiate traditional education: "The lesson for progressive education is that it requires…a philosophy of education based upon a philosophy of experience" (662), and this philosophy of experience radicalizes the role of the individual learner.

Dewey's philosophy of experience is worked out first as *epistemic* project, that is, as a revolution in how students come to *know*, and therefore participate fruitfully with the past, but with full awareness and acquaintance with a changing world. His project, wittingly or unwittingly, provides the philosophical pre-conditions which are necessary precisely for the goods that all future technologies promise to deliver: preparation for an "x"-century world, receding influence of authoritarian teachers, and the empowerment of individuated and self-directed learning, with technological advancements that make it all possible. In other words, Dewey successfully democratized educational *theory* more than fifty years before technological advances democratized *information*.

To be fair Dewey forcefully argued that teachers were critical to the process of education. In spite of his objection to traditional education and methods, he nevertheless located responsibility for education in the instructor as an arbiter of the students' experience (668), albeit a reconstructed teacher with a thorough-going understanding of a progressive role and mandate as a steward of children. He repudiated any view of education that merely objected to the traditionalist model, and he insisted that "the rejection of the philosophy and practice of tradition education sets a new type of difficult educational problem for those who believe in the new type of education" (660). He was clear in his conviction that mere "departure from the old solves no problems" (660). Thus, he advocated for highly trained teachers who carried a thoroughly developed philosophy into the classroom.

Dewey's acknowledged the central problem with his philosophy of experience (664-665). If "experience" were to stand as the locus of truth, he accepted the burden of a criterion "by which to discriminate between experiences which are educative and those which are mis-educative" (665). In terms of instruction, he placed a heavy burden upon instructors to "be aware of the general principle of the shaping of actual experience by environing [*sic*] conditions…[and] that they also recognize in the concrete what surroundings are conducive to having experiences that lead to growth" (668). Thus, Dewey retains an elevated view of a teacher-centric classroom, while blazing large swaths of margin for an individuated and experiential classroom. Far from being a by-stander in the process, the progressive teacher would be aware of the intangible qualities of the learning environment that would impact the effectiveness of his pedagogy.

Dewey never imagined that the kind of technological advancements that his intellectual heirs would have at their disposal would in many ways claim to fulfill his dream of experiential learning. Nor did he foresee that those very advancements would militate against his model of the teacher as the director of learning in the classroom. As a review of the literature by Erneling clearly shows, "the role of the teacher in the new computer-dominated schools is that of a movtivator and a coach, not a provider of information. (Erneling 59). Computer technology is providing children with opportunities to learn in a situation that is markedly different from traditional classrooms settings which Dewey presumably would applaud. He would emphatically reject, however, what some computer use advocates readily advance: that the "teacher is standing on the sidelines helping in this process, but not really shaping it. The learning is seen to be actively constructing his or her own beliefs and ideas in context different from traditional schools…with teachers more like coaches, or even parents" (53).

While Dewey did not claim to have swept the field, his ideas were so widely influential that they forced a cultural shift in how children are viewed in the educational process. It is fair to say that by the late 20th century there had been "a turning away from transmission theories, which define learning as the transmission of beliefs, ideas, theories, and skills to the pupil, who passively receives the pre-ordered material" (48). The advent of computers and digital technology – unforeseen by Dewey – nevertheless comport very well with the broad contours of his theory of learning. Today, the positive claim for SADAT in the classroom is that they aid "internalist theories" of knowledge (49).

It would be too much to insist that computer pedagogies fulfill Dewey's vision of the experiential classroom. On the one hand, they tend to validate it insofar as computers hold forth promises of extended experience and intrinsic motivation. On the other hand, theories of cognitive development after Dewey have tended to reinforce the autonomy of the learner, such that students tend to wiggle away from teachers whom he imagined would implement a broader broader social agenda.

Summarily, Dewey rejects any traditional claim to fixed first principles that form the core of traditional education. "The organized subject-matter of the adult and the specialist cannot provide the starting point" (677-678). Additionally, in Dewey's thinking the path of Progressive education is actually more difficult because it requires the careful working out of meaning from an ever-expanding base of information – information which must be worked out from the student's experience, not from a pre-existing transcendent. Thus, we attach "more importance, not less, to ideas as ideas than do other methods" (679). For Dewey there are no "normative" fact structures; there is no "Ideal Type," and there are no durative, transcendent values, at least those derived from non-scientific sources.

Most importantly, however, Dewey believed that "the scientific method is the only authentic means at our command for getting at the significance of our everyday experiences of the world in which we live" (679-680). Progressive currents, for which Dewey stands as the prophet, were not offered as improvements upon one or the other streams of traditional education; rather, they called into question the content and methods of the entire traditonal paradigm. As such, they not only served as catalysts to reform the American system in practical terms, but they signaled a radical shift in the purposes and methods of the traditional approach. As Dewey says in *Experience and Education*,

> "The traditional scheme is, in essence, one of imposition from above and from outside. It imposes adult standards, subject matter, and methods upon those who are only growing slowly toward maturity. The gap is so great that the required subject-matter, the methods of learning and of behaving are foreign to the existing capacities of the young... Consequently they must be imposed; even though good teachers will use devices of art to cover the imposition so as to relieve it of obviously brutal features" (655-656).

As America moved steadily away from an agrarian context, education moved steadily away from its classical, traditional moorings. Influenced by modernity, riding the wave of the still-young age of modern science, educational philosophers beginning with Dewey, clearly sought to rethink education in the face of industrialization aided by technology, in order to accommodate or intentionally conform to a more complex society. The progressive project was not merely a response to the external pressures of modern life; rather it involved a total re-thinking of the learner, the learning context, and, eventually the preparation of teachers for the new understanding of what it meant to be human in the democratic context. Universal co-education was only one of many symbols of the change in the way education was conceived.

Our comparison of traditonal education and that of Progressivism suggests that education reform beginning with Dewey centers on basic philosophical commitments. Dewey not only advocates a more "modern" approach to learning theory; he is motivated by antipathy to what traditonal education had become – static, resistant to change, insistent upon the transmission of a set of values that appeared to be elitist, outdated, and indefensibly religious. His solution was to advocate an educational approach that was common, modern and secular.

The comparison of the the foregoing approaches is important because it informs the narrative of educational reform at theoretical level. Decades before new technology exploded, the philosophical rift between the Traditional and the Progressive worlds was both manifest and widening. Public education, increasingly secularized, largely avoids the questions (and possible answers) raised in a traditional, liberal arts framework. Such a framework may have been Christian or not; but it was never secular, that is, in the modern sense – totally divorced from any religiously transcendent reference. To state it more charitably, while curriculum in the public context may take up questions that were staple in the liberal arts tradition, it largely rules out serious consideration of any religious contribution or solution to the great questions.

The difference between Traditionalists and Progressivists over the fundamental vision of what education should be, is an important background to the current debate over technology. The educational vision informs the ends to which technology is deployed, which is the subject of the next section.

Part II – SADAT and Education

A. Defining Technology

At the time Dewey was at the height of his influence in the early 20th century, new technologies emerged and were quickly hailed as the fulfillment of the Progressive imagination. The succession of these technologies has been chronicled by Larry Cuban (1986). In *Teachers and Machines* he not only identifies the leading technologies, but suggests a pattern to their lifespans.

That pattern is fourfold. Cuban notes that as technologies are introduced 1) early assertions are that the new technology will change schools. Early studies quickly appear and show 2) that effectiveness of the new technology is equal or superior to traditional modes of instruction. Then there is 3) eventual evidence that universal use of the technology has failed or has been under-delivered, a reality often blamed on technical problems or "pedagogical conservatism" or of teaching cultures. Finally, 4) studies appear that are skeptical of the original claims regarding the effectiveness of the new technology (Cuban, cited in Erneling 41-42).

The historical phases begin with Educational Film, which was an application of Thomas Edison's remarkable invention. Introduced in the late 1920's, contemporary with the zenith of Dewey's influence, this technology persisted into the mid-20th century, and "was an officially endorsed symbol of 'modern' and 'progressive' teaching" (Cuban, cited in Selwyn 46). It eventually fell into disuse because it demanded time from instructors, more central coordination, and more adapted classrooms. Of course, like all technologies after it, it required better support which was often lacking.

The second wave of technology arrived in the form of educational Radio, from the early to mid-20th century. It seems strange to us, but radio generated higher expectation, perhaps because of its effective use in political applications and in theaters of war. Its promise for bringing information to the classroom was unquestioned as millions of people could listen to the President live in fireside chats. But as early as the 1940's, educational radio began to fall into disuse due to equipment availability, to ineffective scheduling, to lack of information (amazingly), poor reception, programming not related to curriculum, and finally with teachers simply not interested in using it.

In the 1950's forward the next educational wave was education television. Initially there was more potential for TV than for film and radio, because TV offered the promise of providing near real-life experiences. As Cuban said, "TV was hurled at teachers" (52). No matter. Its decline was similar to that of educational radio, similarly impeded by cost, lack of teacher training, and low-quality programming. It was simply too difficult for ETV programmers to dial into vastly disparate curriculums that were in use in a large and diverse population.

In order to succeed, ETV would have required a kind of standardized, if not centralized curriculum or educational plan, for which the culture was not nearly prepared. ETV is unlike the internet, which is more quickly adaptable in the hands of a skilled teacher. Thus, while ETV persisted into 1980's, it fell into near-universal disuse thereafter. The life of its hardware was only extended through recording media, first with VHF cassettes and eventually CD-ROM media. Digital technology has replaced both entirely.

The advent of computer technology in the 1970's held the biggest promise by far. Early computers were limited in memory and power, but were found to be useful for tutorial and coaching, drill and practice. As the computer power increased they were more useful for problem solving, as dialogue systems, simulation/computer-as lab system, and database use.

Eventually, educational games appeared and often mimicked the modalities mentioned above, only with competitive entertainment components as a context.

Early educational use was sporadic, even where it was offered, because computers were usually set up in lab or other dedicated rooms, restricting full access from teachers and students. Moreover, they were mostly dedicated to "drill and practice and tutorial" software. Add to those limitations a lack of training and continued teacher resistance, and the widespread use of computers, except in the richest of school systems, was spotty.

History suggests that advocates of new technologies in the classroom for nearly one hundred years almost always envision their technologies as heralding a new era in education, redefining or transcending what education has heretofore achieved. In other words new technologies are introduced with claims for how they will not only revolutionize educational potential, but that the introduction of these technologies is self-evidently justified even to the point of retro-informing the fundamental purposes of education. This is what Erneling refers to as the "the catalyst rationale…that computers are revolutionizing society, the school, even the pupil's cognitive abilities…and, of signal importance, there is the pedagogical rational of improving learning" (Erneling 40).

Neil Selwyn argues, however, that educational technologies in particular have to be assessed in a social context. He points out that "it makes little sense to see digital technologies as simply 'part of the furniture' of educational settings. Indeed, educational technologies are not simply neutral tools that are used in benign ways within educational contexts. Like all other technologies, educational technology is intrinsically linked with the social, cultural, economic and political aspects of society" (Selwyn 17).

> "…we've unfortunately been brainwashed into thinking that educational technologies are neutral. We imagine that tablets and computers are merely tools that transmit unbiased

> academic content to students. On the contrary, they do much more than that. Embedded in every technological solution is a moral/ethical stance, an image of the good life, and a narrative of the idealized self. The worldwide success of Apple's marketing is evidence enough that digital gadgets are not only tools with which we manipulate our environment, but also props in a performed identity narrative" (Shapiro).

Thus, the introduction of any particular technology into an educational context necessarily requires self-conscious determination regarding its role. At the outset, therefore, when considering how SADAT might be deployed in any educational environment, it is important to provide not only a definition of education, but also to clarify a philosophy of education. This is distinguished from theories of learning discussed later.

The technologies of educational radio, film, and TV are largely passive forms of SADAT technology. Students simply watched or listened to the programming offered through the medium. The advent of the PC, which rapidly expanded to include small, more powerful and nimble digital technologies, expanded the horizon of learning toward active versus merely passive learning. The individualization of SADAT has not only made it possible, but is significantly differentiated from the last fifty years of technological advancement, insofar as it promotes the active participation of the user.

B. Modes of Technology

The literature therefore focuses upon the use of newer technology in three modes, with most studies approaching technology with one of several functions. We can distinguish three major categories. First, there are studies that focus on computer assisted instruction (CAI) which contemplates a teacher using technology of any sort in the presentation of material. This may or may not be limited to "presentational" modes, but emphasizes the use of a computer to mediate the material one-on-one to the student.

This is distinguished from computer managed instruction (CMI), “whereby the computer is used to provide learning objectives, learning resources, and assessment of learner performance. Computer-managed instruction (CMI) aids the instructor in instructional management without actually doing the teaching” (Payne). Both CAI and CMI contemplate a more passive role for the teacher, what could be termed “teacher-as-facilitator.

Both CAI and CMI are distinguished from a third modality, computer enhanced instruction (CEI), which assumes the active presence of an instructor who evaluates and guides learners in the process of education.

The argument of this paper is a response to the immense societal and political pressure placed upon educators generally to produce students who leave their schools with the necessary knowledge, skill and maturity to function and thrive in a complex world. The cultural expectation is that technology, if made universally available and properly applied, will contribute to achieving this goal.

In this section I will examine relevant studies on the use of technology in the classroom. While there is a great deal published on the question, nevertheless, there is a remarkably small body of literature arising from tightly controlled studies, meaning that much of what passes for evidence on the question is anecdotal or only correlational. Of the careful studies that have been conducted, the data is at best mixed and points away from a conclusion that technology has statistically significant impacts on learning. These data show that technology has little discernable, positive effect on outcomes, at least as measured by test scores. While the available rigorous studies are limited, there is a large body of more anedotal evidence in the literature. Many of these studies take the form of surveys and are expected to yield data with broader objectives than their methods can support.

Finally, my data do not contemplate the sociological questions such as whether or not technology levels the playing field. I am not considering the question of how technology may provide for the possibility for greater equity in education. Nor do I consider the question of diversity of education, or how technology may contribute to diminished barriers between populations by increasing individual control.

C. Research Data

Angrist and Lavy, 2002

Joshua Angrist and Victor Lavy provide detailed analysis of the project funded by the Israeli State Lottery in which computers were installed in a significant number of elementary schools (10%) and middle schools (45%).   It provided one of the early observable laboratories for which computer assisted learning (CAI) could be studied. Computer technology at the time was sufficiently advanced that students' interface was realistic, and the funding was sufficiently large as to provide a broad enough sample for observing "educational consequences" (Angrist). The study is significant due to the presence of controlled comparisons.

The project, called the *Tomorrow-98 Programme*, was funded not only for hardware and software, but also provided for teacher training, a key deficiency in many other educational contexts. Between the years 1994-1996, 52,000 computers were installed on the basis of an application process initiated by individual jurisdictions, and the target student-computer ratio for placement in any school was set at 10:1, a goal that was to be achieved by 1998. In the end, the average school received about 40 computers.

Data was not collected in all disciplines, but principally in math and Hebrew and only for students in grade 4 and grade 8, with tests designed by the National Institute for Testing and Evaluation (NITE).   NITE is roughly the Israeli equivalent of the National Assessment of

Educational Progress (NAEP). NITE not only collected the data from its test, but also collected demographic data on students, differentiating between male/female students, immigrants, special education students and disadvantaged students. It also controlled for students who had pre-existing computer experience outside of the school and those who did not.

Additionally, NITE administered surveys of teachers designed to discover exactly how much use each instructor made of the available technology. The study was careful to control for exactly when, and for how long the technology had been available, and perhaps most importantly, it measured the intensity of computer use by teachers for instruction, and by students for learning. Finally, the NITE relied upon historical achievement test data provided by the Ministry of Education for comparative purposes.

The findings of this study, which admittedly possessed its own limitations, such as "bureaucratic guidelines and idiosyncratic elements," nevertheless represent some of the clearest empirical findings available. Angrist & Lavy found that "while there is clear evidence that computers funded by Tomorrow-98 led to an increase in CAI at least in 4th grade, there is no evidence that this translated into higher test scores. The only statistically significant test score difference is the *negative* effect on 4th grade Maths (*sic*) scores, and two out of three of the other groups show *negative* effects (emphasis mine)" (749). Thus, "the results reported here do not support the view that CAI improves learning, at least as measured by pupil test scores" (Angrist). This finding confirmed the study's hypothesis "that the theoretical case for CAI is not well developed, and there are good reasons to believe that computers can actually be a diversion" (736).

The results certainly do not compare with other efforts such as controlling or reducing class sizes, for example, or increasing teaching training, which have a much higher and observable impact on test scores. While it is not the concern of this paper, it is worth noting that the finding of Angrist & Lavy support skepticism when estimating the cost/benefit of expenditures on technology in the classroom.

Fuchs and Woesmann, 2004

In a slightly newer study by Thomas Fuchs and Ludger Woessmann, both of the Ifo Institute for Economic Research at the University of Munich, student achievement was measured from a different angle. Fuchs & Woessmann wanted to know if students who had access to computers at home *and* at school had higher achievement. They point out that popular advocacy for universal access to computers in both environments must contribute to higher literacy, academic performance and achievement. This claim is not altogether without merit, as there is a demonstrated correlation between computers in the home and achievement.

This study employed data from the Programme for International Student Assessment (PISA), a test proctored to 15-year old students in 32 countries. It also collected background data from PISA questionnaires provided to participating schools, together with other data on national average expenditures and per pupil spending, and whether or not schools had curriculum-based external exit exams.

Equally important the study had to account for computers in two environments, neither of which provided comparable accessibility. Some students had one computer at home, while others had more than one. In the school environment access to computers is on a varying student-computer ratio. Moreover, the study accounted for intensity of use, not only for how many times a week a computer was used, but how it was used – checking e-mail, playing games, working on schoolwork or recreational uses. Finally, the study was concerned to account for whether students had access to, or were using educational software. Similar controls were used for the school setting, such as how many computers there were, and whether those computers had internet access.

Perhaps the most important aspect of the Fuchs and Woessmann study was the attempt to overcome the Achilles heel of studies of this nature: "the essence of the problem of identifying effects of computer availability and using observational data, because the computer effects can easily be confounded by effects of other factors. If these other variables are omitted from the empirical estimation, they will bias the estimated effect of computers" (8). Those other factors, of course, are the relative socio-economic status, educational background of parents, family structures, etc., which wildly affect outcomes. Using the PISA data from background questionnaires, the study attempted to control for these and similar factors. "By directly controlling for the economic, social and educational environment at home in a multivariate analysis, we can at least make sure that any estimated effect of computers will not be driven by these other observable characteristics." (8).

Fuchs and Woessmann showed that students with no computers at home compared negatively with those who had more than one. In an "unconditional performance" score, that is, when not controlling for all of the outside factors, the difference between these groups of students is "approximately equal to a whole grade difference" (12). Once the control variables are regressively added in however, the differences become statistically insignificant. Thus, the drivers in student success are not attributable to the presence of computers but to the total family-social context.

A shocking aspect of the study, however, reveals that when the home environment of advantaged students – those whose homes support more than one computer – is coupled with schools that provide computer resources, there is a statistically significant *negative* impact on student performance not only in math, but also in reading. Fuchs and Woessmann conclude that "in sum, the results cast strong doubt that the mere availability of computers at home and at school does a lot to advance students' educational performance. While bivariate results would suggest that there is a positive relationship in both cases, these results are *spurious*. Once other features of student, family and school background are held constant, computer availability at home shows a strong statistically significant *negative* relationship to math and reading performance, and computer availability at school is unrelated to performance" (14).

This study also attempted to detect a correlation between student achievement and computer use at school on the basis of intensity. The study found a statistically significant higher outcome in math scores among students who used computers several times a month over those who used them rarely. This was not true for reading. However, students who used computers several times per week performed significantly *worse* in math and reading. This extended to internet use as well. Those students who had no access to the internet performed lower in math and reading, but those who had high levels of access to the internet performed *lower still*. A possible explanation, of course, is that over-exposure to any one modality of education crowds out other teaching approaches to the detriment of the student.

The studies cited above are cherry-picked, of course. For every study that shows that computers do not contribute significantly to student achievement, advocates can produce others that do. The above studies were chosen, however, because of the significant controls on the effects of other factors, which is often seriously lacking in studies of this kind. The difficulty with studies of computer technology is that the effects of the technology are easily confounded by other factors. If those variables are omitted from the study, the result is biased at least, and useless at worst, an outcome that both preceding studies sought to avoid.

James A. Kulik, 2003

To balance the two primary studies above, what follows is a summary of a review of multiple studies by James A. Kulik (2003) at the University of Michigan, Effects of Using Instructional Technology in Elementary and Secondary Schools: What Controlled Evaluation Studies Say. Kulik reviewed studies in three categories: reading (27 studies), writing (12 studies), and math & science (36 studies). Kulik's approach is two-fold. First, it is a meta-analysis, i.e., analysis of analyses, which is common, but second, Kulik relies on "effect size" measures to summarize results, a practice that was novel in the early 2000's in research reviews.

Effect size is a mathematical method that makes it possible to perform statistical analysis for a variety of studies under consideration in which they can be expressed "on a common scale of effect size" (6), which can then be correlated to other measures, such as a percentile scores. Thus, as shown in the table (page 31), ME = median effect. In the first example where the ME is recorded, Writing-based Programs, the ME for kindergarteners was .84 (very strong). This correlates to a move in percentile scores from the 50^{th} to the 80^{th} percentile. In the last case, which was of studies of microcomputer-based labs where simulations were offered for students' use, the results were trivial with an ME of only .01.

The results of Kulik's study are mixed, with the highest positive influence of computers primarily in mathematics. Integrated Learning Systems (ILS) in math showed the "the ILS effect was large enough to be considered both statistically significant and educationally meaningful." Computer tutorials in specific science topics yielded similar results. Yet, the same systems in reading do not yield quite as significant scores. A variety of factors may explain this, but the usual variable is likely to rest with incomplete implementation, which has long plagued the use computers in the classroom.

Overall, Kulik is optimistic. On the one hand, he admits that the data are difficult to capture, that studies are uneven, and that strong positive support "seems patchy" (60). The trend, however, is toward sustained presence of technology in classrooms – it isn't going away – and that students are more tech-savvy. In addition, teachers are perhaps increasingly more receptive to technology.

Reading Studies – 27	Description	Outcome
Integrated Learning Systems (9)	Sequential instruction of over several grades (Kulik, 16)	ILSs have done little to improve teaching effectiveness of reading programs. ILSs do not usually make meaningful contributions to reading improvement in elementary schools (Kulik, 5)
Writing-based (12) Reading Programs	Uses writing as a mode of teaching reading	Strong positive results in kindergarten [ME = .84 SD > 50^{th}-80^{th} percentile]; less effective in grade 1[ME = .40 SD > 50^{th}-66^{th} percentile], and smaller effects thereafter [ME = .25 SD > 50^{th}-60^{th} percentile] (Kulik v-vi)
Reading Management Programs	Accelerated Reader	Suggest that AR helps students improve their reading skills, but the results are not conclusive. Too few controlled studies of AR are available for firm conclusions, and further controlled evaluation studies of AR are needed [ME = .43 SD > 50^{th}-67^{th} percentile] (Kulik, vi)
Writing Studies – 12		
Word Processing	Decades long studies showing differences between hand written papers and word processor	Students who use word processors for writing compositions demonstrate superior writing skills in later follow-up tests of writing skills. word processing effects are usually small, but support use in schools [ME = .30 SD > 50^{th}-62^{nd} percentile]
Computer Writing Prompts (2)	Word processor programs that provide prompts while student use them	Together, the studies suggest that the effectiveness of writing prompts may depend on how the writing prompts are presented. More research is needed to confirm this conclusion.
Computer Enrichment (6)	Unstructured time to students to use the internet, participate in exercises, games, simulations and tutorial programs	Five out of the six studies found that computer enrichment helped students to improve their writing skills. In the remaining study, computer enrichment had a small, statistically significant, negative effect on student writing. [ME = .34 SD > 50^{th}-63^{rd} percentile]
Mathematics and Science – 36		
Integrated Learning Systems (16)	Sequential instruction of over several grades	Each of the 16 studies found that mathematics test scores were at least slightly higher in the group taught with an ILS, and in nine of the studies, the ILS effect was large enough to be *considered both statistically significant and educationally meaningful*. [ME = .38 SD > 50^{th}-65^{th} percentile] (Kulik, viii)
Computer Tutorials (6)	Focus on specific science topics taught in specific courses	In all but one of the six cases, the effect of computer tutoring was large enough to be considered both statistically significant and educationally meaningful. [ME = .59 SD > 50^{th}-72^{nd} percentile]
Computer Simulations (6)	Provide science students with theoretical or simplified models of real-world phenomena	[ME = .32 SD > 50^{th}-63^{rd} percentile]
Microcomputer –based Laboratories (8)	Computers collect data and immediately convert the analog data into digital input, displayed graphically. MBLs show phenomenon in the laboratory while viewing the development of a graph describing the phenomenon.	It was difficult to find studies, and the results were mixed. [ME = .01 – trivial effects]

Part III – SADAT in the Context of Leading Educational Theory

A charitable treatment of the above evidence, mixed as it is, suggests that SADAT is at least sometimes effective in student achievement. Careful research and even flawed studies do show that test scores can be moved in some disciplines at some grade levels, even when there is no overwhelming evidence that suggests children who have across-the-board access to technology are significantly advantaged for having had the benefit. According to Selwyn, "For every large-scale study or 'meta-study'…that concludes that technology use can be associated with improvements in learning performance, there are many others that find no difference, or even a negative relationship" (85). Nevertheless, the use of computers as a pedagogical tool is not only pronounced, but it continues to grow. The conclusion does not point us in the direction of resistance to this trend, but to insist on effectiveness in an effort to serve the student. What the studies do not explain, even when they show positive results, is "how and why computers are effective" (Erneling, 46).

Advocates of Computer Assisted Instruction (CAI), Computer Managed Instruction (CMI) or Computer Enhanced Instruction (CEI), argue that various modes of technologies cause learning in different contexts. While it is evident that digital technology can support education in a variety of contexts, it does not follow that the presence of technology will deliver all that supporters claim. The hope that educators have placed in universal access to this or that technology may be misguided, as the evidence above suggests. One hundred years of history show that innovators in technology, and many professional educators quickly latch onto to the latest technology, determined that such technology represents the final necessary breakthrough need to crack the conundrum of declining test scores and the demonstrated illiteracy of many at various functional levels.

Purveyors of computers and software, policy makers who purchase them, and educators who use them, have very different perspectives, and each responds to what Selwyn refers to as external imperatives. Innovators and purveyors of computers obviously have a profit motive; policy makers are under public pressure to appear relevant and current, teachers simply wish to teach, and if technology is present, they want it to be seamless. All three groups want to keep up with the rest of modern life and not fall behind the times; meet the demands of the knowledge economy; provide for the essential capabilities of contemporary life; and meet the expectations of students and parents" (23-25).

Regardless of whether computer technology consistently fulfills expectations of higher test scores and broader student achievement, we should examine the fact that computer technology tends to be deployed in terms of existing education theories. When students are given access to technology, they are not suddenly transformed into wholly-other students, a new kind of learner teachers have rarely encountered. The reality is that students continue to be students, more or less interested in the tasks given them, and that the deployment of computer technology tends to support pedagogies of pre-existing theories of cognition.

A tacit assumption on the part of many educators pertains to remarkable advances in brain research that suggest that students might "think and process information fundamentally differently from their predecessors" (Prensky, 2001, cited in Selwyn 65). It has been shown that the human brain exhibits remarkable plasticity, which is to say that it is continually able to adapt to input, and "has the ability to reprogram itself on the fly, altering the way it functions" (Carr 26-27). Not only is this true for victims of brain trauma, but it is also true for aging adults whose brains "are always breaking old connections and forming new ones" (26). If this is true, it is reasonable to exploit technologies that could take advantage of such plasticity if we could identify those technologies, and if they could be shown to contribute positively to the re-mapping of the brain itself, and if there were proven to be an advantage in learning.

As recently as 2009, however, the journal *Science* published the findings of Patricia Greenfield, a developmental psychologist at UCLA. Her findings, after reviewing fifty studies regarding the effect of media on different types of intelligence and learning, revealed that "every medium develops some cognitive skills at the expense of others" (Carr 141). Touchscreen technology, and browsers that endlessly open internet sites and landing pages have contributed positively to our ability to "rotate objects in our minds…but [they] weaken…our capacities for the kind of deep processing that underpins mindful knowledge acquisition, inductive analysis, critical thinking, imagination, and reflection" (141). The research on this question remains nascent, and it is possible that screen-based technologies merely re-direct our brains to function in different – not necessarily detrimental – ways.

There is remarkable variation among educational theorists about how humans learn. The theories of Skinner and Piaget, which I note below, differ dramatically, and thus we should anticipate variances in how they are reconciled to advancing technology. After all, digital technology came into existence long after the leading cognitive theories in education were developed, affording us the unique opportunity to test the theories, *post facto*, against the evidence of the high-tech, digital classroom experience.

We could frame the question this way: Does SADAT reasonably promise a breakthrough in educational theory, offering modifications to current theories of cognition? Does it thus open to us a truly revolutionary breakthrough in how humans think and learn, or, will we discover at the end of the day that SADAT merely affirms the truth of existing claims about human cognition? If the former is true, then the future of education might be driven to new frontiers in what could only be labeled a paradigm shift. If the latter is true, then technology will appear to trope existing theory, which is to say that it doesn't fundamentally advance our understanding of learning, but can be selectively defended and advocated by practitioners of different theoretical persuasions.

On the one hand, new frontiers of technology and the methods afforded by digital learning might confirm one theory or the other, or perhaps elements of several theories. If such proved to be the case, it could point educators in a general direction around which all sides could make common advocacy. On the other hand, it may be that applied technology presents us with the preconditions of a completely new account of human learning, possibly leading to new horizons of educational theory heretofore unknown. As Selwyn suggests, "technology-based learning requires *new* theories of learning that account directly for what takes place when individuals use digital technologies" (80).

This is precisely the question raised by Christina Erneling, who recognizes that in the hard sciences, there has been a tendency to see what Thomas Kuhn identified as a paradigm shift, that is, a sequential and total displacement of one theory by a subsequent theory, such that the older theory is nearly discarded for practical purposes. In other words scientific advancement is not to be understood as the successive improvement of one scientist on another, although this is partially true. Rather, in the physical sciences the most significant advancements took place when one ontological conception of the world was replaced by another.

Erneling points out that Stephen Toulmin's book, Foresight and Understanding: An Enquiry into the Aims of Science, ironically makes a contrasting claim in the area of psychology – a year before Kuhn's book appeared. What Kuhn called the "paradigm shift" in the natural sciences is referred to in psychology as "ideals of natural order." Toulmin showed that, unlike the natural sciences, competing ideals of natural order in the cognitive sciences do not displace one another; on the contrary, they tend to co-exist for long periods of time (26). Thus, while behavioral theories of Watson and Skinner were dominant in the mid-twentieth century and no longer carry the day in teachers' colleges, they nevertheless persist in the mainstream in wide variety of sub disciplines, even though newer theories enjoy intellectual hegemony in their place.

Given the tendency toward long life-spans and co-existence between cognitive theories, it is unlikely that computer technology would sweep the field of cognitive development with something on the order of a Copernican Revolution. We are likely more correct to predict that computer technology is deployed consciously or unconsciously in the service of one or another existing theory. The question is not academic; there are practical implications not only for policy makers who are responsible for allocating limited resources for education, but also for teachers on the front line of learning. It is puzzling, therefore, that "the literature on educational computer technology seldom explicitly states what assumptions or theories of learning inform the arguments for the educational use of computers" (46-47).

Instead of leading to a sea-change in education theory, technology might amount to little more than a "Trojan Mouse," that is, nothing other than a means to advance an already-existing philosophy of teaching and learning into educational settings (Selwyn 89). In sum, educational theories developed in the 20th century were not constructed to account for how digital technology effects (or affects) learning. Selwyn broadens this claim to assert the total non-neutrality of technology: "…educational technologies are not simply neutral tools that are used in benign ways within educational contexts. Like all other technologies, educational technology is intrinsically linked with the social, cultural, economic and political aspects of society" (17).

Theories of Cognition: Behavioral

Behavioral theories are the best place to begin, not only because they are older, but because the leading behavior pioneer, B.F. Skinner, specifically applied his psychological model to educational pursuits. The basic tenets of Behaviorism are well known, even though there are more than a half dozen sub-schools of thought in the tradition. They each subscribe to a view of learning as largely passive in the learning process, but responding through positive and negative reinforcement. Intramural disagreements exist over the role of external and internal stimuli.

The stimulus/response behaviors Ivan Pavlov demonstrated with respect to salivary glands in dogs are well known as are the sensitization techniques John Watson controversially attempted to prove in the "Little Albert" experiment. Both of these vivid but simple examples contribute to the popular understanding of Behaviorism, making it easy to oversimplify its theoretical claims. Skinner himself believed that knowledge is action and that the learner must play an active role in acquiring knowledge. While instructional theories have moved away from Behaviorism as a satisfactory account of cognition, Skinner's contemporary champions continue to make the case for his basic commitments (Burton, Moore, & Magliaro). Moreover, Behaviorism continues to make a remarkable contribution in diverse areas from counseling to the treatment of autism.

Believing that traditional teaching was undermined by the lag between the work that a student produced and the feedback that a teacher was able to give, Skinner theorized that students would learn faster if they had immediate feedback to the accuracy of their knowledge or skills and if the feedback could be conveyed both immediately and in a form of reward. Thus, while still a graduate student at Harvard he created what came to be known as the "Skinner Box" through which pigeons and other animals could "learn" a series of behaviors based solely on food motivation. Certain behaviors were rewarded until they were “internalized,” at which point the reward was eliminated, with the result that the bird could ultimately perform a long series of acquired skills.

Applying the principles of conditioning to students, Skinner actually precipitated a new technology in education, the Teaching Machine, which was the first effort at programmed instruction ever proposed. By today’s standards it was very low technology, but was remarkable for its day. The contraption consisted of a physical box that could sit on a student’s desk and which could be programmed mechanically to offer confirmation to answers of preset questions that could be viewed through a window in the top. The device individualized the learning process, provided self-paced progress, and most importantly, offered immediate feedback to the user. Moreover, it could be calibrated to the level of difficulty needed for students at different skill levels.

The Teaching Machine persisted up into the 1960’s, and was regarded as successful (Selwyn 69), though it never achieved the hype that preceded educational radio or TV. The Teaching Machine, while not electronic, provided the basic theoretical architecture of early computing devices, and anticipated early computers. Both relied heavily upon Behaviorist theories for software development. Disciplines such as reading and math facts lent themselves easily to “drill-and-skill” formats in which the Teaching Machine had previously specialized. The early computers performed the same task, but merely changed the medium of delivery.

The application of computers in developed in a Behavioral model should be appreciated, especially in areas where skill levels and knowledge bases are vital for performing certain tasks. This includes many vocational and technical disciplines that require requisite practical knowledge or sequential knowledge. For example, learning to operate heavy equipment, learning a policy procedure, or mastering a series of steps to problem solve, each lends itself to this kind of software application. Any sequence of knowledge that must be mastered in order to direct behavior, can be supported by Behavioral theories deployed in computer applications. Indeed, millions of people encounter drill-for-skill software routinely, without knowing that Skinner contributed to the method. Classroom computers of the Computer Assisted Instruction (CAI) mode rely heavily on this theory of cognition, such that we can confidently say that "early on in the educational use of computers, the common theory of learning referred to took the form of different versions of Behaviorism" (Erneling 48).

The Teaching Machine and the computers that mimic its function assume passivity, a dependency in the student, to follow the program wherever it leads, but with little to no opportunity for deviation from the correct answer. The student is active insofar as he responds to input from the device at hand. As a theory, however, Behaviorism provides a limited narrative for human cognition, so much so that educational methods that descend from it can be viewed more as a way of teaching, rather than as an explanation of learning (Selwyn 68). This kind of computer technology does not in itself represent a revolution in learning, although it may have very legitimate applications for pedagogy. In the early days of computer technology, keyboards and hard drives more or less replaced the Teaching Machines that Skinner had curiously devised, but remained committed to the principles of his theory. Behaviorist theories, therefore, have been shown to undergird computer aided instruction, but they are challenged by more recent cognitive and constructionist theories that offer challenges to the sufficiency of Behaviorism's explanation of human learning. These argue for wider social constructs for learning.

Theories of Cognition: Constructivism

While Behaviorism retains a loyal following, educational theorists since the mid-twentieth century are dominated by the theories of Jean Piaget, "in theories of pedagogy, in developmental psychology, and also to some extent in cognitive psychology" (Erneling 48). If Dewey cleared the way for progressives to repudiate classical, liberal education, Piaget provided a thorough-going cognitive theory to replace it. After Dewey, the American academy was turning away from the liberal arts view of education as a transmission of values, the pursuit of the Ideal Type, or as an external body of knowledge preserved and handed down institutionally by the guardians of culture. With Piaget, we find a revolution moving from externalist ideals to internalist ones (49).

Constructivist theories magnify the innate biologial structure of the developing child. Children seemingly learn massive amounts on their own, and they do it by internal compulsion. This is not to suggest that the environment does not matter, it is simply to acknowledge that such skills as speaking, walking, or navigating the house or neighborhood are acquired naturally in accord with internal motivations. Normal children learn to speak without formal instruction, but they do so inductively as they imitate and respond to what they hear. For Piaget, learning is a natural, biological process in response to environmental conditions, and development is "fundamentally…a result of the individual acting on his or her own" (Piaget, cited in Erneling 71).

The most well-known aspect of Piaget's thought is his stage theory. According to this theory children progress in maturation through four stages of development: 1) the sensory motor stage from birth to around two years of age; 2) the pre-operational stage, during which time children learn to speak, but do not possess the abilities of abstraction; 3) the concrete operational stage, which lasts to around age eleven; and 4) the formal operational stage from around age eleven or twelve into adulthood, during which they acquire the ability to think logically, and with greater amounts of abstract thought. These stages are relatively even and a child will develop cognitively as long as there is a normal environment with normal opportunities (Erneling 71).[1]

The central claim in Piaget's thinking is that children learn by constructing information for themselves. Learning is an active process, not exclusive of input from teachers or the environment, but a process nonetheless, in which the child must actively create new constructs from existing ones. A child moves from simpler constructs to complex constructs with "operational learning," and thus, learning is "scaffolded" as the student progresses. When a child encounters information that does not fit with existing constructs, he experiences disequilibrium, which, when resoved, results in transformation of knowledge. In Piaget's understanding, knowledge is highly *personalized* because learning is highly *individualized*, conditioned upon one's own experience and inquiry.

It is not difficult to understand why computer technology is near-universal in its acceptance among educators of this persuasion. Technology appears to be a "key means of facilitating a learner's exploration and construction of knowledge" (Selwyn 74). It has the capacity to isolate the student to his own pace, to calibrate learning to his ability, and the limitless potential to expose the student to vast amounts of information which serves as grist for his delight-directed response.

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[1] It may be the case that Dorothy L. Sayers was influenced by Piaget's stage-theory when she articulated her own stages of the poll-parrot, the pert, and the poetic in her *The Lost Tools of Learning, 1947*. (Piaget's theories did not enjoy popular notice until the 1960's, while Sayers died in 1957). Nonetheless, she treats the Trivium as no one before her did, reducing it in some ways to a stage-theory pedagogy rather than viewing (as Joseph does) the Trivium as the core of the curriculum itself. Many educators involved in the current recovery of classical education read Sayers as a kind of handbook on pedagogy, with curriculums that are informed by her thought at least on broad points. Nevertheless, classical educators do not seem as consciously committed to Piaget's claims and minimize the presence of technology in their classrooms.

David Jonassen summarizes the principles of computer use in the classroom as congruent with Piaget's constructivism in at least seven different ways, four of which are keenly relevant: 1) computers often present problem-based knowledge construction vs. the mere knowledge reproduction; 2) it can support collaborative construction of knowledge through social negotiation, rather than competition among learners for recognition; 3) it encourages thoughtful reflection on experience; and 4) it encourages "child-like view of learning through building, making things, and attributing inanimate objects with their own intelligence" (Jonassen, cited in Selwyn 74-75).

As theories go, Piaget's Constructivism could not have anticipated the technical revolution with better timing. Teachers of the 60's, 70's and 80's, who stocked their classrooms with artifacts, items of interest and other real-world enticements, believed they would spark spontaneous learning by providing the kindling with which to build an intellectual bonfire. None of it compares, however, to the private laptop or tablet, a WIFI connection, a built-in camera monitor, a Smart Board, and a short-throw projection screen upon which to transmit or display the results of one's connectivity. The Constructivist is more than satisfied with the advancements of the virtual world, committed as he is to the certainty that students in seventh grade will as eagerly learn as they did as two-year olds. Computer technology appears to confirm and exploit the assertion, but in doing so, it runs the risk of sidelining the teacher who surely helps in the process, but does not really shape it (Erneling 33).

The objection to Constructivism is to its assertion that learning in later stages of cognitive development is like infant learning. If young children have a biological determination toward spontaneous and self-motivated learning, and demonstrate the capacity to learn on their own, then all secondary cognitive skills follow in the same way (12). This is by no means settled science. It is highly contestable that children simply learn to walk and talk on their own, as a learning entity to themselves. Children are born into social structures and learn language dogmatically, relying upon others – their parents, for example – to provide meaning within shared framework. This remains true for subsequent knowledge acquisition. Children do not sustain interest in discrete particles of knowledge, if that knowledge is removed from larger frameworks of meaning, meaning which they rely upon teachers to provide. Piaget assures us that students transform knowledge through disequilibrium as though any resistance is overcome by internal, biologic motivation. Such is not the case, however; students are resistant to change, especially if they perceive that there are no criteria for truth. As Erneling asserts, secondary cognitive skills such as "critical learning is especially difficult because it…requires that the child be encouraged to question not only his or her own beliefs…but those of other pupils, as well as those of the teacher" (164). Thus, children must learn many things dogmatically – starting with their mother tongue, which means that the K-12 classroom must be teacher-instructed, not merely teacher directed.

Computers utilized in the service of Constructivist theories are deployed on the assumption that children learn on their own. Because computers contain the "wow" factor and because they individualize learning, educators intuit that the learning is taking place as long as computers are central to the learning process. In other words, because the technology is present, and the technology contributes to individual exploration, learning automatically happens. It's not possible to know if Piaget would have agreed; he died in 1980, before computers became widely available. We do know that Constructivist theory reigns in the educational community, and the arguments for advancing technology in the classroom inevitably result in challenging the tradition role of teachers, while over-estimating the positive contribution that computers can make. The problem is not with computers *per se,* but "how they are utilized in specific situations…which at least partly explains the failure of computers as educational tools" (178).

Conclusion

I began this inquiry by comparing Traditional, classical education and the Progressivism of John Dewey in order to provide the broadest context for understanding the advances in technology in the digital era. By contrasting these two approaches to education, I have tried to show that competing visions of education in America were in conflict decades before computer technology emerged, and that technology has actually accentuated the basic aims of disparate traditions. In the classical tradition, there is resistance to ceding control of the educational process to child-centric experiences, untethered from normative ideals, or to the "reality" of the virtual world. This resistance is centered in the commitment to a teacher-as-text approach, in which a real person brings knowledge and wisdom to a student *personally*. Classical inquiry developed as a way to foster face-to-face engagement, genuine curiosity, imaginative hypotheses, and methods of testing conclusions (Hicks 18).

Progressive education "distrusts the classical schoolmaster's tolerance for normative questions and for the use of methods appropriate to those questions," with misgivings rooted in a commitment to experimental verification, or belying a lack of sympathy with the goals of the classical educator (19). Practitioners who subscribe to Behavioral or Constructivist theories may not necessarily share Progressivism's basic commitments, but in the chase for the shiny new tools of technology, such practitioners may suffer the effects of unintended consequences. Theories of cognition pertain to the psychology of the learner, but "matters of technology and learning cannot be broached without consideration of the essentially ethical question of what counts as worthwhile learning, whether for liberal or vocational ends. [These] assumptions involve a commitment to a particular set of values…often at odds with…wider social contexts" (Paul Standish, cited in Selwyn 89-90).

In comparing the different visions, we each make our own value judgments as to which of the underlying commitments is better. Still, we need not elevate all estimations of technology to value-laden judgments. Thus, in the second section of this paper, we surveyed representative studies that offer a snapshot of empirical evidence – at least as accurately as we can measure it – in order to determine whether computer technology contributes to overall student achievement. Our finding is uneven and mixed. While computer technology can and does support learning, so far it has not revolutionized the learning *process*, at least as evidenced by test scores.

Computer technology has achieved near-miraculous access to information, connected social groups that would otherwise remain ignorant of one another, and opened up avenues of exploration not previously accessible. All of these are goods in their own right, but they represent outcomes to different questions. However beneficial these outcomes may be, they should be distinguished from performative test data. These other goods may point to the advantageousness of computer technology in providing and presenting resources, without proving that such advantages translate into higher performance. As Richard Clark quips "There may be…benefits to be had from using technology to deliver learning….nevertheless, media do not cause learning…Grocery trucks have little impact on our nutrition. They merely deliver food. That is how technology works" (cited in Selwyn 87).

Thus, finally, we turned our examination to two leading theories of cognitive development, Behaviorism and Constructivism, seeking to show that computer technology is generally contextualized into existing learning theories. Computer technology has not uncovered or unleashed a new theory of human cognition, and to our knowledge, there is has not been an attempt to formulate new a theory in response to current research. Such research is emerging, as Carr has shown, and the early indicators suggest that the brain does respond differently to various kinds of media, especially book-based vs. back-lit screen and distractible world of the mouse click or hyper-text.

This leads to the conclusion that computer technology promotes, if not intensifies, tendencies that are resident in current educational philosophies. The debate therefore comes back to one's view of the purpose of education. An over-reliance upon computer technology suggests that education

> "is about teaching youngsters that exploring what's on a two-dimensional screen is more important than playing with real objects, or sitting down to an attentive conversation with a friend, a parent, or a teacher. By extension, it means downplaying the importance of conversation, of careful listening, and of expressing oneself in person with acuity and individuality. In the process, it may also limit the development of children's imaginations" (Oppenheimer).

This project has raised the question of whether technology fulfills its promise to revolutionize the learning *process* in traditional schools. It challenges the popular assumption that technology is an unqualified good, and that it should unquestionably be deployed in the classroom context. We conclude that technology fulfills many other expectations, but does not yet point to a fundamental change in learning theory. It should therefore be deployed in the classroom with an awareness of goals consistent with the educational theories of the practitioner.

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