EFFECTIVE AND MEANINGFUL USE OF EDUCATIONAL TECHNOLOGY: THREE CASES FROM THE CLASSROOM

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I. INTRODUCTION

The shift from steam to electric power was gradual and costly, not just because of the required investments in technology, but because the technology enabled and required fundamentally new ways of organizing and conducting work. Technology in schools today is ubiquitous. Educational technology makes bold claims of efficiency, interactivity, and the ability to provide instantaneous, useful information for teachers to teach better and for students to learn more. There are numerous forces that have pressed for technology to take an active role in K-12 classrooms. These pressures are primarily rooted in an economic argument that stipulates our students must compete on a global stage. To keep pace with our economic competitors (e.g., China and India) technology in the classroom has become the most recent edition to the constant call for educational reforms. The press to create new normative practices in our schools with new technologies is nothing new. Sadly, like many educational reformation predecessors, the research, development, and legislative policies that anchor 21st century reform in technology remain largely underutilized and unrealized.

A number of reasons have been given to explain this gap between espoused and actual use. To begin, a digital divide remains from school to school. Inner city and rural schools continue to have problems of access to digital technologies. Beyond the issue of access loom two other key barriers to the use of technology: the readiness capacity (knowledge and motivation) of individuals to effectively use technologies and the capacity of the technology itself to make a meaningful contribution to both teaching and learning in schools.

Our work has six anchors of advancing pedagogical change with technology. We support the conceptual and empirical literature that build the capacity of teachers, educational leaders, students through interactive technology. Our anchors, based both on strong scientific research and our experiences, are beliefs that:

1) Teachers are the most important in-school variable to impact student learning.
2) Teachers can acquire the necessary knowledge to effectively utilize advanced technologies in the classroom.
3) Teachers must find a reason to change their practice – that is changing professional practice will require doable, observable, and compatible features;
4) Principals and other educational leaders must develop the knowledge, skills, and dispositions to resource and support a clear and viable vision for educational technologies;
5) Technology platforms exist that merge a tool that builds teacher capacity with interactive capabilities such as professional development, curricular alignment, leadership, etc.
6) Students are culturally disposed to be actively engaged in technologies—today students can create, edit, and comment on content instantaneously and globally. Additionally, the normative practices associated with technology must not exclude elements of collegiality, cooperation, collaboration—elements often dismissed in the midst of focused reform efforts.

In the end, the nexus of student learning resides within these anchors that will drive dynamic teaching.
To advance student achievement, educational technologies must provide students with interactive experiences (e.g., real-time global student-to-student communication) and teachers with timely, specific information about student learning and misconceptions (e.g., real-time specific information on what and how students are learning)\textsuperscript{12,13}. Studies have revealed substantial learning gains with frequent and focused feedback\textsuperscript{14}. Shute’s\textsuperscript{14} meta-analysis of formative feedback revealed .40 to .80 $SD$ gains in student learning. She likens formative feedback to a murder; That is, “effective and useful feedback depends on three things: (a) \textit{motive} (the student needs it), (b) \textit{opportunity} (the student receives it in time to use it), and (c) \textit{means} (the student is able and willing to use it)”\textsuperscript{15}. Such systems exist. There are systems that provide timely feedback, mechanisms verification, error flagging, and strategic hints\textsuperscript{16,17}.

Today, many teachers are being asked to use educational technology in their classrooms for tasks that may not enrich their teaching. That is to say, teachers are looking for technologies to enhance not transform their practices. However research has indicated that when teachers find that technology supports the curriculum and advantages student learning they used technology more than others\textsuperscript{18}. Piaget\textsuperscript{19} explained that it is cognitively natural for one’s schema to be self-serving and therefore resistant accommodating new ideas to formulate new schema. Seymour Papert\textsuperscript{20} highlighted how technology resides in the periphery of teaching practices because of the inability to crack the code of pre-existing schema or practices: “it is a characteristic of conservative systems that accommodation will come only when the opportunity of assimilation have been exhausted.” To obtain such accommodation technology must be integrated with content and pedagogy during the act of teaching; this is known as Technological Pedagogical Content Knowledge (TPCK)\textsuperscript{21}. Combining the right technology tool with the elements of change theory may lead to transformational or evolutionary uses of technology\textsuperscript{22,23} and schema accommodation.

The purpose of this chapter is to describe an intelligent tutoring system that is designed to extend already proven effective teaching practices and transform teaching practices. This technology is well situated to create new normative pedagogical practices as it rooted in the aforementioned six anchors of advancing pedagogical change with technology. Specifically, relative advantage for teachers using this technology is garnered through ease-of-use, efficiency, and the ability to observe improvements in student engagement. We begin with a brief overview of the tutoring system. Next, we provide three compelling examples of the system in action. We conclude with a discussion on what these illustrations of use tell us about teaching and learning with intelligent tutoring systems.

II. EXPLANATION OF ASSISTMENTS

ASSISTments is a web-based assessment system that provides tutoring based on student responses. The system is so named because it is a blend of \textit{assessMENT} and instructional \textit{ASSIST}ance. This system collects data efficiently and provides student-level diagnostic results - what we call cognitively diagnostic - that allow teachers to monitor students’ progressions through the cognitive model. The cognitive model is based on 130 specific math skills. These were designed by dissecting the Massachusetts states Frameworks and other curriculum lists into individual skills or knowledge components. Examples of the skills are “Venn Diagram,” “Percent of,” “Area of a Circle,” and “Area of an Irregular Figure.” A list of knowledge components is available at www.assistments.org. The system is not designed to “teacher proof” the classroom. In fact, ASSISTments is designed to augment, replicate, and promote good
teaching practices including: uncovering detailed diagnosis of misconceptions, providing immediate, specific feedback, and monitor student practice.

ASSISTments has over 1000 tutored items in middle school math. Tutored means that if a student gets the problem wrong, they are given scaffolding questions, associated hints, and buggy messages. Figure 1 shows a screenshot of a single ASSISTment. For this ASSISTment, the student must know two skills: “Venn Diagram” and “Percent of.” A student who gets the main problem right will move on to another problem. If not, as in this example, they will get tutoring. In this image we see that the student incorrectly typed “8,” to which the system responded, “Hmm, no. Let me break this down for you.” The tutor then asked the student a scaffolding question. In this case, the student is asked to find the “Percent of students in Biology, Algebra, and Band.” We see that the student had to look at one hint to answer this question. This hint consists of an image to show that the student had to add up the percents in gray. The next scaffolding question follows up on the first and this student got it right. The last question asks the original question again. This student typed in 23400 and given a “buggy message” reminding her that she did not check to see that her answer was reasonable (it must be less than 900). The system then reminded her that when multiplying by .27 she did not move the decimal over two points. Once the student actually types in the correct answer of 234 the student can proceed to the next ASSISTment. The original question is tagged with two skills where the individual scaffolding questions are just tagged with one each allowing the teacher to assign problems with more than one skill. Then individual skills can be diagnoses by looking at the results of the scaffold questions.
Note how this student received individualized context-sensitive just-in-time-help, while the teacher does not have “do” to any grading. By breaking questions into steps, the tutor is able to provide cognitively diagnostic information to teachers: which items are students getting right, which scaffold questions are they getting right, and what are common wrong answers. If the teacher looks at a report of this student’s work on this problem, they would see the student had a little trouble with the first “Venn Diagram” question, had no trouble on the second, and had a little trouble with the “Percent of” skill in the third scaffolding question.

Figure 2 shows a teacher’s item report where his students have done four ASSISTments in a row (items #4517, #8842, #4674 and #78). A teacher can see that over half of his students got the first question wrong on their first attempt (if they have to ask for a hint they are marked wrong). However, they seem to have learned from the tutoring and gotten the next two questions correct. The fourth item, ASSISTment #78, only 29% of students could get the item correct. The teacher sees that ASSISTment #78 also has the knowledge component of “Percent Of” in addition to “Venn Diagram.” He can see the common mistakes students made on the Original Question: 18% of his students answered “0” while 12% answered “657.”

In addition to this cognitively diagnostic data as seen in Figure 2, ASSISTments can be used for Mastery Learning and since it is online can be sent home for nightly homework. While the digital divide is a genuine concern many communities have public computers that if given a few days students can access outside of school. Parental notification is a feature that allows teachers to easily inform parents about how their child is performing and what they have, and have not, mastered. This saves the teacher tremendous amounts of time and enhances teacher, student parent communication. All of these features are designed to enhance what the teacher is already doing but allow them to do them in a more efficient manner thus connecting to anchor 1, taking advantage of the teacher as the most important resource, and 3, having the technology enhance what the teacher already does.

An innovative use of ASSISTments that a handful of teachers are pioneering is what we call Advanced Student Response System. This feature allows teachers to create their questions (on the fly or prepared), ask the students to respond, anonymously post the answers using a projector, and generate rich, meaningful discussions. This provides instantaneous feedback by students to either questions teachers provide or to others student’s work shown to the class with a projector or smart board.

This system comes with a student response system that also includes essay grading and provides a teacher friendly presentation system. As more and more teachers who use ASSISTments have projectors in their classrooms the advantages of sharing the data with students in class has emerged. In fact, when students have access to computers at the same time as the teacher can project the results on the screen we have seen the classroom light up with
discussion. These discussions can be instantly followed up by more data collection creating a dialogue loop that involves every student responding to the teachers questions online and having their answers recorded on ASSISTments and projected for everyone to see.

In conclusion, the ASSISTments project has resulted in over three dozen peer-reviewed publications. ASSISTments has been funded by the Spencer Foundation, Office of Naval Research, National Science Foundation, and the Department of Education. We have used ASSISTments as a research platform to conduct experiments about what is the best way of tutoring students. We also have published six peer-reviewed studies on ASSISTments as an assessment tool. For instance, we know that we get better assessment if we look at how much assistance they need as measured by how many attempts they need to take to answer correctly how many hints they ask for, and how many seconds they spend on a question. We also know that by tracking 130 knowledge components in 8th grade math we can better predict students’ state test scores, which speaks to the reliability and validity of our knowledge component mapping. Finally we are beginning to run randomized controlled experiments in classes to see how using ASSISTments affects student learning. One such study showed that when students received feedback and tutoring at home they had greater learning gains then when they received feedback the following day.

II. ASSISTMENTS IN ACTION IN REAL CLASSROOMS.

ASSISTments provides real-time cognitively diagnostic data to teachers and students to improve student learning and to inform teaching. At a minimum, students are told instantly if they are right or wrong. More importantly they are also given support in the form of questions and hints while they are being assessed. In addition, teachers can use ASSISTments for Mastery Learning and have the system perform all the associated bookkeeping functions. ASSISTments is used in computer labs, on laptops in classrooms and at home and public libraries. Many teachers are taking this tool and using it in innovate ways to enhance their teaching helping their students make real strides in learning.

In this section we closely examine the work of a number of real teachers who are using ASSISTments to inform their teaching and help their student achieve. They use it for Nightly Homework, Mastery Learning, and an Advanced Student Response System. Together these teachers demonstrate the flexibility and responsiveness of these features to help teachers build on what they already do in order to teach more effectively.

II.A. Homework

As the Web and technology become more common in schools and the digital divide closes at home, more schools are using technology for nightly homework. Nightly homework is an important part of extended classroom learning. This system allows teachers to participate in our third anchor of using technology to enhance a current practice. Teachers are able to streamline the grading, help to students and assessing that are all part of the homework process.

The traditional homework routine involves sending a set number of problems home with students, they do their best and then they come in the next day to see what they got wrong and get support on questions they have. With ASSISTments, teachers select the problems they assign for homework, students get feedback in the form of correctness response and sometimes tutoring, and then the teacher reviews and plans around the reports in the morning before class. They can even share the data with the class by just pulling up and projecting the item report (see Figure 2) from the homework. For students without Internet access, the teachers have the option of printing
a handout. Currently ASSISTments has hundreds of premade questions available including Connected Math Project (CMP) questions, content from statewide test questions, and hundreds of other items written with handcrafted tutoring.

Dr. Heffernan and his colleagues found that simply completing nightly homework on ASSISTments produces more learning that paper and pencil alone. This echoes what other researchers have found in other disciplines. In this section we will describe how one teacher Ms. Tignor uses these pre-made problems with tutoring and how another teacher Ms. Mulcahy uses ASSISTments along with her normal homework from her book.

Ms. Tignor works at a technical school where she sees her students every other week during their "Academic" Week. The other week is called "Shop" Week where they learn vocational skills. When she first started using ASSISTments she asked her 10th grade students if they would rather do weeklong review homework over the Class Week or over Shop Week. They overwhelmingly voted to do it over Shop Week. This started their routine where she assigns a problem set of challenging problems (with ASSISTments tutoring) from the high-stakes statewide assessment test (MCAS in Massachusetts) for them to solve outside of class online. The state test is given in March to 10th graders and passing is a graduation requirement. Each student must score a proficient or take review math classes and take the exam again. Ms. Tignor’s goals for this homework assignment are for students to: 1) Work on problems to practice for the exam, 2) Get help in the form of ASSISTments tutoring on any problem they get wrong, and 3) Write up solutions for the problems they get wrong. With these three goals in mind, she gets her students involved in assessing how well prepared they are for the state exam, they get help and the also have to show her what they understand after reading through the tutoring.

This routine starts on Friday when Ms. Tignor assigns the homework. She reinforces the need to show their work by having students turn in their original work in an organized fashion. She also gives them a worksheet to fill out if they get the problem wrong. Ms. Tignor knows that the open response portion of the State test where students must explain their work is the most challenging. She values their explanations so she gives each student a rubric designed to focus their work on explaining and help her in assessing their work.

In our example here, Ms. Tignor assigns a problem set. At home, students log into ASSISTments and start working. They use their graphic organizer to show their work so Ms. Tignor and they can reference it later. As an example let’s follow the work of a student, Jessica. Jessica finished the problem set using her graphic organizer (Figure 3). Since she got this question wrong she now needs to work through the tutoring on ASSISTments and then write an explanation herself for Ms. Tignor. Figure 4 shows what she wrote for this problem to find the measure of angle B.

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All students who get a problem wrong initially see ASSISTments tutoring to help them work through the problem (see Figure 1). The problem stays open on the screen as you see in Figure 1 so students can refer back to the tutoring to help them write their explanations. Students who go back to fill out their corrections have to go to their
individual item report which is an individual view of the item report in Figure 2 just showing the row for one student. Jessica got 5 of the 10 problems wrong so she had to turn in 5 worked out problems. Ms. Tignor only has to look at the work of students who could not solve the problem and need to be monitored on their work.

One great benefit of assigning homework online is that Ms. Tignor does not have to wait until Monday to monitor how the whole class is doing. As you can see from Figure 2, Ms. Tignor can get data such as percent correct for each problem, most common wrong answer, how many students did not even attempt the problems and how many students went to a bottom out hint while working on the scaffolding. She then uses this data to assess her students and make instructional plans for the next week.

As part of her effort to assess students’ writing Ms. Tignor keeps a folder for each student with a list of the assignments they have worked on (see Figure 5). She records the original percent correct calculated by the system and an adjusted quiz score. These scores are kept in the folder and the folder is later used for student teacher conferences.

Ms. Tignor has two routines that she uses to respond to the data she collects. 1) On Thursdays, she adds one or two of the problems from the previous week’s homework to class work as a warm up problem. For example, one week only a third of the students got a problem correct. Ms. Tignor finds it beneficial to have a discussion about a topic that was clearly confusing to many students. 2) Once a month during the weekly exam, Ms. Tignor confers with each student on his or her progress and his or her work on ASSISTments is discussed. During these meetings Ms. Tignor offered suggestions on their writing as well.

This activity involves a lot of training of the students to learn to write about their math and show their work as well as manage their time over Shop Week. Ms. Tignor feels that the effort she puts into it really pays off. She is able to get students to concentrate their efforts on the problems they get wrong. She is also happy to send them off for a week to work because she knows they are getting support in solving difficult problems from the system. She responds to the class on problems where the majority of the class had issues, and she holds individual conferences with every student where they discuss their written responses so that each student understands where they are in their process of achieving their goals.

Another teacher, Ms. O’Connor, who works at an suburban middle school and sends home her regular nightly homework as ASSISTments and has written ASSISTments to allow students to input their answers online and get correct feedback. Students are told which problem to do in their text (for example the ASSISTments will just say Page 12 # 6 and have a space for the student to put in the answer.) They start by doing the problem on paper because Ms. O’Connor values having the work organized and able to be referenced in class. Then they input the answer in the system and click submit. They are instantly told if they are correct and either try again if it is wrong or move on to the next problem if it is correct. Ms. O’Connor has not had time to write hints or other support for these problems but the system allows for her to go in and
add hints and other tutoring when she has the time. Ms. O’Connor checks the homework data before class and uses it to plan.

These examples illustrate how teachers use this feature differently. It also highlights how this feature harnesses technology to (1) link the home and school whereby parents can be integrally involved in student work, (2) create efficiency in the teacher ability to understand individual student learning prior to the next class meeting, and (3) allow students to engage in homework in an electronic manner—capturing today’s adolescents desire to work in a technological environment.

II.B. Mastery Learning

In this section, we will describe the Mastery Learning feature of ASSISTments. Mastery Learning gives students practice on a single skill from the ASSISTments list of 130 skills. A major challenge of Mastery Learning is the bookkeeping. Keeping track of skill development is a time consuming and detail-oriented task. Teachers need to keep track of the skills each student has and has not mastered, who having trouble mastering a skill, and what the prerequisites are for each skill.

ASSISTments keeps track of all of these things for teachers, students and parents. The Mastery Learning feature focuses on single skill items like solving an equation or adding fractions unlike most problems in ASSISTments that require students to use multiple skills (e.g., ASSISTment # 78 that requires “Venn diagram” and “Percent of” from Figure 1.) Different students need different amounts of practice to demonstrate mastery of a skill to themselves and their teachers. Building enough content for this sort of practice is the most important part of mastery learning. ASSISTments uses variabized problems allowing each problem developed to become a set of problems measuring the same skill but with different numbers or names. This keeps the students practicing.

Additionally, of the 130 knowledge components we can track, we have a prerequisite structure already in place. For example, for a student to master Pythagorean Theorem, they need to have mastered equation solving and square roots. This tagging allows a student who is struggling in a knowledge component to move back to a prerequisite skill before continuing with the original skill.

If a problem set in ASSISTments is tagged with Mastery Learning it automatically tracks the amount of practice a student gets depending on how well they are answering the questions. Most of the problem sets are set so a student “masters” the skill once they get set number of problems correct in a row. Students who know the skill can demonstrate that quickly. Students who do not know the skill must work until do master the skill. Students who are getting problems wrong get help from the ASSISTments tutoring or they can seek help from other sources. Teachers can monitor students using a simple report (see Figure 6) and seek out students who are struggling and give help.

Figure 6 – Bulletin board in Mr. Burnett’s classroom depicting weekly assignments for Period 2 – his preAlgebra class.
Ms. Mulcahey, who teaches at an urban middle school, gives out one Mastery Learning problem set each night to her suburban 8th grade students. At the beginning of the year she selected skills that they should have mastered in 7th grade and monitored their progress. Many students made errors but were able to Mastery in one or two days. Ms. Mulcahey monitored and addressed the students who did not master. Next year she is planning to include the special education teachers who work with some of her students in monitoring the data. Later in the year she selects skills that she has covered. Waiting a few weeks before giving this review. This simple problem set just ads a few minutes to her student’s nightly homework and is an important part of her ability to give her students the practice they need.

Mr. Burnett is a suburban middle school teacher who uses ASSISTments exclusively for Mastery Learning. His students head to the computer lab every other week and get a new assignment of Mastery Learning problem sets for students to do. The students only get started in the lab, they then have to finish the work at home during the week. He polled his students at the beginning of the school year and found only two did not have internet access at home. These students have opportunities to complete the work outside of class but during the school day:

*I use Mastery Learning to reinforce learning from classroom and to pinpoint any problems or weaknesses. I use ASSISTments as a two tiered system: 1) it allows me to have students work independently using hints when they struggle and to come to me when they just cannot get over that hump on their own, and 2) it works as a great motivator to some students – they really work hard to see that word “mastered” next to the assignment.* (Mr. Andrew Burnett)

Mr. Burnett monitors the students’ progress by referencing the Mastery Learning progress report (Figure 6). The report tells the teacher if the student mastered or is still working. It tells how many problems the student did in there quest to master and how long they spent. In this report Mr. Burnett can see that Student 1 and 6 mastered after only 2 problems (the mastery criterion) so they got no problems incorrect. Interestingly student 6 did this in only 34 seconds showing great understanding while student 1 took 3.5 minutes. Student 4 finally mastered but after doing 18 problem, and interestingly did them in 8.5 minutes compared with the 17 minutes it took Student 3 to master after 11 tries.

Like Ms. Mulcahey, Mr. Burnett selected review content at the beginning of the year. This allowed him an efficient way to give practice only to those who need it. As a conclusion to the mastery activity he put together a regular ASSISTments problem set with one problem per skill to help him and the students monitor their overall progress on those review skills.

The Mastery Learning feature provides a platform for teachers to allow students to practice as much as they need on a skill by skill basis. Also because of the reports as students practice teachers can monitor their students strengths and weaknesses in these skills. The
technology that allows for templates with variables to build large sets of problems. ASSISTments also has an authoring tool available that, with training, allows anyone to build these problem sets on any skill they want.

III. C. ADVANCED STUDENT RESPONSE SYSTEM.

We have shown that ASSISTments is an efficient and interactive tool increase teacher efficiency. We have discussed how teachers use the over 4000 problems with tutoring as Nightly Homework and that ASSISTments can take on the onerous task of the bookkeeping involved in Mastery Learning. Next we will show how ASSISTments handles the important task of writing and reading explanations of solution strategies. The NCTM Standards includes communication in mathematics as one of the standards that can improve student understanding of mathematical concepts.

Today’s math teachers are being asked to get students to explain their work verbally and in writing. They are also asked to include writing in their math classrooms. ASSISTments helps teachers orchestrate discussions and assess student’s explanations of their work. Beyond declarative, factual knowledge and memorization the Advanced Student Response System in ASSISTments provide student with procedural knowledge attainment and communication in mathematics. Procedural knowledge is a vital component to the deep understanding of mathematical knowledge and skills. Following is an example of a teacher who uses ASSISTments to help her build the communications skills of her students.

When a teacher wants a student to explain in ASSISTments they select the question type “Open Response” in contrast to the question types “Fill In [the blank]” and “Multiple Choice.” In this question type a box is provided for students to type their explanation. The one drawback to this answer type is that unlike the others ASSISTments cannot grade these items. To facilitate these responses there is a special link to a feature called “Essay Grading.” Once teachers link to this page they see the question and then the selection of essays written by the students next to their names. They are then able to grade the essay from 1 to 4. Once this is done the grade changes from “ungraded” to the percent in the regular item report (see Figure 2) and the average changes. If a teacher wants to review the essays with the class teachers can select just a few exemplary essays and only have them show up for the discussion allowing the teacher to focus the discussion on the essays that move the learning objectives forward. In this next section we will walk through the steps used by a teacher using this system.

In the final days of a unit on linear equations, Ms. O’Connor gave an ASSISTments problem set that included regular “Fill In [the blank]” ASSISTments and one “Open Response” ASSISTments. Figure 8 shows the questions she gave for this assignment. The numerical answers are graded automatically freeing up Ms. O’Connor’s time to review and reflect on the students written explanations. Figure 9 shows the item report she gets that has the essays in it. Once she collected all the explanations and read through them on ASSISTments she selected a few of the explanations to use in class. She wants students to (1) know their explanations will be read and possibly shared with other students and (2) read other student’s explanations. In reading each other’s explanations students both learn the math, by being exposed to another students solution strategy, and learn how to write better explanations themselves.

Ms. O’Connor learned a lot by looking at the data that came in from this activity (Figure 9). First, all but one of her students got the right answers to A - D. so she know they all had a strong understanding of the procedural parts of this problem. Armed with that information Ms. O’Connor began to review the responses to E. This question asked students to justify their
answer by explaining how the number of club members go on the trip should effect their decision. Ms. O'Connor has been working on explanations with her students. She is looking for clear use of vocabulary, getting the right answer and clearly explaining how they go their answer. She finds that the best way to improve explanations like this is to have students read and discuss each others work.

To prepare for this work Ms. O'Connor carefully selected the 5 essays shown in Figure 9 to show a variety of levels of understanding and misunderstanding. For example Student 1 made an error in just looking at the y-intercept and not taking note of the per person rate. Student 2 Answers the question for 72 (which are the numbers calculated in A and B). He also mentions the break-even point of 100 skiers but he does not explain how this number effects the decision. Student 3 gives a very nice explanation clearly explaining which number of students should choose each company. The student is clear that at 100 either company could be chosen and she also explains how the set fee and the rate per person effect this. Student 4 must have done some work to find 100 but does not clarify anything in his explanation. Student 5 did not even understand that there was a point where the two companies would be equal. He just selected 50 students and argued that for that number Mountain Charter would be cheaper. All of these points and more are discussed in class as Ms. O'Connor goes over the responses with the class.

In this case, the advance student response system allowed Ms. O'Connor to be more efficient and more effective as a teacher. The activity described here allowed students to not only give explanations that were easily read and graded by the teacher but it also allowed the teacher...
to share selected explanations with the rest of the class and have them discuss those responses. As a result, accountability of a lesson is no longer between the teacher and the student. With these types of advanced technologies work becomes more public. In essence, student work becomes interactive with the teacher, peers, and with themselves. Making student work more public, while safeguarding student anonymity, is a powerful tool in advancing student learning.

IV. IMPLICATIONS TO THE FUTURE OF TEACHING AND LEARNING PRACTICES IN SCHOOLS

Educational reforms have promised much and delivered very little. There are many reasons why including 1) that the reform designers are often non-educators, 2) professional are risk adverse, 3) the school and district organization is highly bureaucratic and often dysfunctional, and 4) education as an institution has a tradition of morphing reform to mirror current practices and routines. As a result, one should not be surprised that technologies have not had a pronounced impact in education as it has in other aspects of our lives. A district principal in Clippert Schools in Detroit said the following when asked why technology failed to take root in schools:

Current development is retarded by many factors: Lack of adequate funds for equipment and research, mechanical developments too rapid to keep pace with, stable teaching practice, ...[and] advertising and ethics.32

This comment was made in 1932 in regard to educational radio programming. Cuban summarized a similar fate for educational television. Like radio, televisions were hurled at teachers. And, the “initial applications to the classroom were conceived, planned, and adopted by non-teachers… reformers had an itch and they got teachers to scratch it for them”33.

So how do we get real, sustainable technological advances in schools? As previously stated, capacity and will to effectively use educational technologies are build on six anchors of advancing pedagogical change with technology. The examples provided in this chapter offer a glimpse of what these anchor may look like in practice including:

- Teachers are freed of routine and mundane administrative tasks such as grading and organizing data in a way that can be quickly used
- Students are asked to reflect on their own work as well as the work of fellow students
- Students are asked to work alone and to collaborate with fellow students
- Teachers are able view summaries of learning as well as specific aspect of possible problem areas
- Students and teachers are able to articulate learning through examinations of both declarative and procedural knowledge
- Students are presented with problem set similar to future testing efforts; and
- The platform is web or cloud-based making access in the new digital divide based only on connectivity

Instructional technologies such as ASSISTments have powerful implications for policy practice, and research. To begin, policy wonks continue to have student assessment and technology in the crosshairs of school reformation. Recently, the National Science Foundation (NSF) and the U.S. Department of Education’s Institute for Education Science (IES) have been
granted a portion of the $787 billion in aid from the American Recovery and Reinvestment Act. Much of the IES money has been targeted to train educators “to use data to identify the specific help students need to succeed, to adjust classroom instruction to better address student strengths and weaknesses, and to target professional development and other resources on student and teacher needs”34. There is a clear and present press to use student achievement data to improve teaching and learning in the same ways that the teachers described above are using data to inform their instruction.

Additionally, this work has major implication for current and future practice of teachers and those who lead and train them. If practice is to change to keep pace with the development of new technologies and the expectation of students then pre-and in-service development efforts must be altered. Moreover, more cloud-based, interactive instructional technologies must be developed and implemented in our schools.

Finally, further research is warranted to understand the utility of instructional technologies like ASSISTments. This research should not only consist of experimental and quasi-experimental studies of student achievement, but also more robust, detailed examinations of school-level educators development and implementation and understanding the students’ engagement.

V. CONCLUSION

The evolution of technology and schooling have proceeded at different rates. Technology has revolutionized offices, stores, airlines, steel plants, hospitals and the military35. Yet schools have remained largely unaffected. Mechanisms of all sorts have been introduced to assist the teacher in teaching children. From the eight-inch leather strap to the New England Primer to Guttenberg’s printing press and the McGuffey Reader to the chalkboard to the electronic mediums of the 20th century, innovations have focused on making teaching more efficient and learning more fruitful. The innovations that had staying power in schools were simple to manipulate, easy to access and efficient for teachers36,37. Chalkboards, textbooks and the duplicating machine have captured these important characteristics. As a result, it can be deducted that the electronic innovations that failed to take hold in schools (e.g., radio and television) lacked the essential characteristics of accessibility, versatility, compatibility and adaptability for teacher use. Not surprisingly, “Chalkboards can write, draw, erase, and keep material for days. Given this flexibility it is no wonder that the chalk-smudged sleeve has become the trademark of the teacher”38.

An educational technology tool does not improve student achievement outcomes any more than a “thermometer cures a fever; both are simply tools”38. In most professions inspection and feedback are not reserved for the end of an activity. For example, builders must pass building codes throughout the construction process. Moreover, professions are provided the necessary tools and training to complete their work. For instance, physicians are provided specific instruments for specific procedures and they are trained in an apprentice-style fashion. Sadly, teachers are not always entering classrooms with the right tools or training. Huff and Goodman posited, “What educators are demanding is that they receive instructionally relevant results from any assessment in which their students are required to participate and that these assessments be sufficiently aligned with classroom practices to be of maximum instructional value”39. The 2001 National Research Council’s Knowing What Students Know clearly articulates the need for assessments designed around modern principles of learning: classroom assessments that “help all students learn and succeed in school by making as clear as possible to
them, their teachers, and other education stakeholders the nature of their accomplishments and the progress of their learning”\textsuperscript{40}.

In the 21\textsuperscript{st} century we have been witness to great advancement in information and communication technologies. Nonetheless, people need training in and out of technology. That is, people need to be trained in the work that computers cannot do. Levy and Murnane\textsuperscript{41} posited that such tasks will include “expert thinking and complex communication.” What is stopping us? Dede stated, "barriers [of educational technology] are not technical or economic but psychological, political and cultural”\textsuperscript{43}. As a result, technologies must be woven into the fabric of the school organization\textsuperscript{44}. Wolcott stated, “educational technologists tend to be preoccupied with solving the problems they know how to solve rather than addressing the problems teachers face”\textsuperscript{45}.

Kling provides another nice analogy, “We do not simply replace horses and mules with cars and trucks. We have configured an elaborate system of motorized transport, including new roads, traffic regulations, gas stations, repair shops, insurance and so on”\textsuperscript{46}. Similarly, systems, structures, and technologies must be developed, implemented, supported, and sustained in schools. The road to the effective and meaningful use of educational technology must be paved with the right technology, but also the right people and the right support and resources. If technologies are to have powerful lasting impacts on the way teachers teach and how much students learn then the technologies that are developed and how they are used matter. Instructional technologies like ASSISTments have the potential to fundamentally alter the normative practices of the teaching profession, and thus the potential to improve student learning.

REFERENCES

3. Here we refer to technology as both electronic advancements as well as new strategic educational and pedagogic approaches. For example, the radio was hailed as revolutionary for teaching practices taking a seat next to the library and newspaper. Levenson added that the radio could “up grade” teaching skills and would be able to amalgamate the learner’s experience into their education by having a “tremendous influence and have adjusted the curriculum, teaching processes, and even administrative practices to take full advantage of this powerful learning aid” (p. v). In regard to teaching practices there have been waves of reforms that have battered the classroom like Open Classrooms and Outcomes Based Education to name a few.
27. Ibid.
29. Ibid.
