EDUCATIONAL TECHNOLOGY: THE NEED FOR BETTER ASSESSMENT STRATEGIES AND FOR CONSIDERATION OF STUDENT LEARNING STYLES, TEACHING STYLES, SPECIFIC TYPES OF PERFORMANCE SCORES, AND STYLES REFLECTED IN THE INDIVIDUAL TECHNOLOGIES

David Singer, EdD
Massachusetts Institute of Technology
singerd@mit.edu

ABSTRACT
The use of technology by students and faculty within classrooms, for homework, and research projects is essentially omnipresent and seems indispensible at this point. We all believe that this will only increase. However, there is little empirical evidence that educational technologies of any variety actually improve student performance. The majority of assessments of educational technologies base their conclusions on subjectively based evaluations and general impressions. Despite this, the application of scientific controls can be achieved. There is also a good rational and empirical evidence concerning what we would need to incorporate in order to realistically specify the benefits of educational technology. This could include the differentiation of the learning styles of students, teaching styles, specific performance scores, and the learning styles reflected in the educational technologies used.

Introduction

Evaluations of the assessment strategies used for educational technologies reveal that little empirical evidence exists that is convincing. Controlled studies using empirical methods that are the framework of psychology and the hard sciences are not common in education. Further, advances in psychology, child development, and neuroscience all point to the need to include additional assessment variables. These include student learning styles, teaching styles, specific performance scores, and the learning styles reflected in the actual software or hardware product.

Assessment

In a review of over 160 papers dealing with the assessment of educational technologies in education, many limitations were discovered. A few of these include the following:

1. There is a not a generally well accepted definition of what constitutes learning in education! The types of performance scores that a student must obtain in order to receive a given grade vary dramatically across schools and campuses. Tests, quizzes, midterms, finals, homework, projects, class participation, etc. have been combined in motley ways to determine how

much a student has learned. However, each type of performance score can reflect a different type of learning, and each can correlate differently with the software or hardware that has been used. In order to assess the effectiveness of a technology, the definition of learning must be clear, widely agreed upon within the school community, and measurable.

2. Assessment usually only deals with the mean change in students' attitudes or performance. Students who perform worse than or better than the mean have not been differentiated. We can ask, for instance, what effect a new educational technology might have for students who might otherwise score near or at the top of their class. On the other hand, it is likely that an educational technology could benefit students who might otherwise do poorly, have a learning disability, a specific learning style, or who might be unmotivated. Our research seems to indicate that (Singer, D.A., Ten Ways You Might Be Fooling Yourself about Assessment, Campus Technology, April, 2006).

3. Less than 10% of evaluations or research on the effect of educational technologies focuses on quantitative measures of student learning or performance. Most evaluations or research base their conclusions on student and teacher opinions, surveys, and anecdotes. These are rarely reliable or valid assessment measures upon which to base conclusions.

4. Popular teaching methods such as collaboration, application of information to real world problems, and hands-on learning methods may not be effective for all students and may be counter-productive for some. As a result, software that incorporates such methodologies may benefit students differently. On the other hand, specific educational technologies may be especially beneficial to certain students. Because of different learning styles, educational technologies affect student performance differently. This can be taken into account in an assessment protocol.

5. Improvements in learning often cannot actually be attributed to the technologies that were being used in schools. Research involving educational technology has historically been very poor. Many investigators do not have training in basic research methodologies.

6. Once methodologies and technologies are in place, it can get harder to apply them consistently. It is a common problem that instructors often fall back on old habits or teaching methods significantly before the school term is over.

7. Student motivation to try a new pedagogy can decrease the validity of the findings. The so-called "novelty effect" increases student motivation and does not address the real question regarding the pedagogical effectiveness of the educational technology. This factor can be easily differentiated in an assessment protocol.

8. An instructor's enthusiasm for educational research can detract from the validity of results. An instructor's enthusiasm or interest in determining the benefits of a new educational

technology can, in itself, improve students' motivation, interest and therefore, performance. This factor can be differentiated in an assessment protocol.

9. An important factor when considering the utility and effectiveness of educational technologies is the amount of time that they are used within the school setting, or after school, or at home. Few schools consider the amount of time that specific technologies are actually used, or are available to students, or the number of different students who use them when they try to assess the benefit of the technologies that they purchased. This is another critical variable. If a student is given the opportunity to spend twice as much time using one software product as another, the time spent learning alone could explain at least some of the improvement in performance.

Controls for these and other factors are essential, and they can be introduced. However, in addition to these types of empirical controls, it would be best to take into account additional factors in order to obtain valid and reliable evidence that a given educational technology can benefit students' learning. I will start by describing the concept of the distributed curve and its relevance to educational assessment. I will then briefly reference brain-based education and learning theory. From there I will discuss student learning styles, teaching styles, and the learning styles reflected in some actual software or hardware products.

Distributed Curve

The relevance and premise of the bell curve is simply that any learning style, any ability, any behavior that we define may have a normal or at least a relatively normal distribution among students or children. It is not difficult to argue that a distribution of any of these parameters may not follow a normal Gaussian curve. It can be skewed and the standard deviations may be of any size. Nevertheless, we can argue that no matter what form a distribution of a learning or behavioral parameter takes, there will be members who are above and below the mean in some measurable distribution. More simply put, we know that no matter what type of teaching methods we use, what type of educational technologies we incorporate, and no matter what basis we use for grading students, some students will benefit more than others independent of ability.

This distributed curve is, as we shall see, essential in trying to assess the benefit of any educational technology and how it might best be used by a teacher or by students.

Learning Theory

Much of learning theory as it evolved in the twentieth century has remained relevant and has been implemented in virtually all teaching methods and in every educational software product in various ways. This includes such obvious variables as positive reinforcement, repetition and distributed learning. However, there are, of course, many other variables that have relevance when we are talking about the impact of teaching styles, learning styles and educational technology in education. For instance, the timing of feedback based upon a student's response is significant. If a student learns that his response to a question or problem was incorrect, most of us would recognize that the sooner the student can get feedback about why he was wrong, the better.

Another example is the use of so-called "hints," such as developed by David Pritchard at MIT. David Pritchard developed an educational software product called CyberTutor. One of its attributes is the opportunity for students to get hints, if need be, about how to solve a particular problem before they try to complete the problem themselves. Incorporating "hints" is a concept within learning theory. That relates to the well-known types of memory called recall and recognition.

The important point to remember is that the degree to which each student benefits from the application of such concepts as positive reinforcement or from teaching methods that incorporate recall or recognition in different ways reflects a distribution of some kind, probably a more-or-less normal distribution as seen in numerous intelligence tests that are used today. For instance, incorporating the use of hints in an educational software product will benefit students to various degrees. Some students will benefit tremendously, others hardly at all.

When we evaluate the concepts of learning theory that are incorporated in any teacher's teaching style, in any student's learning style and in any educational technology, the amalgamation is almost always unique.

Brain-Based Learning

There are many check lists and theories of what it means to incorporate brain-based learning in education. It could be said that the first real effort was developed by Dr. Maria Montessori. Montessori's methods were integrally related to her understanding that neurologically based multisensory and motor experiences were necessary for children to develop normally and fully, and that each child was unique from that vantage point. She believed that learning did not just involve the development of reading and mathematical skills, each of which reflects well-known specific areas and networks of our brains. For instance, she recognized that the development of visual spatial ability and the ability to create three-dimensional models was significantly independent of reading or writing. The brain requires that the child sees and engages with spatial views of objects and creates three-dimensional objects with the hands.* This theory reflects our understanding that very different areas of the human brain are involved in such learning. But regardless of how we define brain-based learning, neuroscience has provided us with a new perspective.

Brain-based education is a perception, a sense, that any legitimate, effective, appropriate teaching method must ultimately have a basis in brain functioning in order to be considered real. It is more convincing than just traditional psychological or educational studies. As such, it compels us to recognize that education is not ultimately a soft science. It must be based upon how our brains function. Advances in neuroscience, including the use of fMRI, PET and MEG technologies, are bringing us to face this at an unprecedented rate. This perspective also helps us to recognize that just as no two individuals have the same fingerprint, no two people have the same brain. No two students respond exactly the same way to one educational teaching method or educational technology - hardware or software.

Learning Styles

The concept of "learning styles" reflects the different ways that we learn. Each child, each student, learns

*Today the Montessori methods are often described in the context of the Constructivist Theory of education. This, however, is a limited view since Montessori methods do not exclude formalized learning methods.

best in different ways even if most students are educated where there is an emphasis on reading and mathematics and even if most students adapt and adjust successfully to these methods. Now we find ourselves increasingly incorporating educational technologies to incorporate different learning styles. This also includes group processes and so called "real world" applications. We think that it is better. It might be in most cases.

The numerous theories of learning styles such as Howard Gardner's Multiple Intelligences, David Kolb's Experiential Learning Theory and even the Myers-Briggs Topology model, as different as they may first seem, can describe theorized neurophysiological underpinnings. Few, in fact, really contradict each other. Whether they might include verbal-mathematical or interpersonal learning styles as described by Howard Gardner, concrete or abstract learning styles as described by Gregorc or any others, we presume that their legitimacy ultimately rests upon their neurological foundations. These foundations are being uncovered.

One student might learn more readily or more comprehensively through verbal skills and benefit from courses that define learning and thus, grades, in terms of reading and answering questions in written form. Another might do better if learning is defined and grades achieved where there is more emphasis placed on the interpretation and creation of spatial configurations (architecture). Each of these two types of learning styles represent well known and distinct networks of the nervous system. Another student might do much better where interpersonal teaching methods, such as those involving group work, are used to help define learning and compute a grade. Another student might learn best through extroversion techniques described by Myers-Briggs. This would include presentation methods of learning and grading students. The areas and circuitry of the human nervous system that would be reflected in each of these preferences are distinct even if there is overlap.

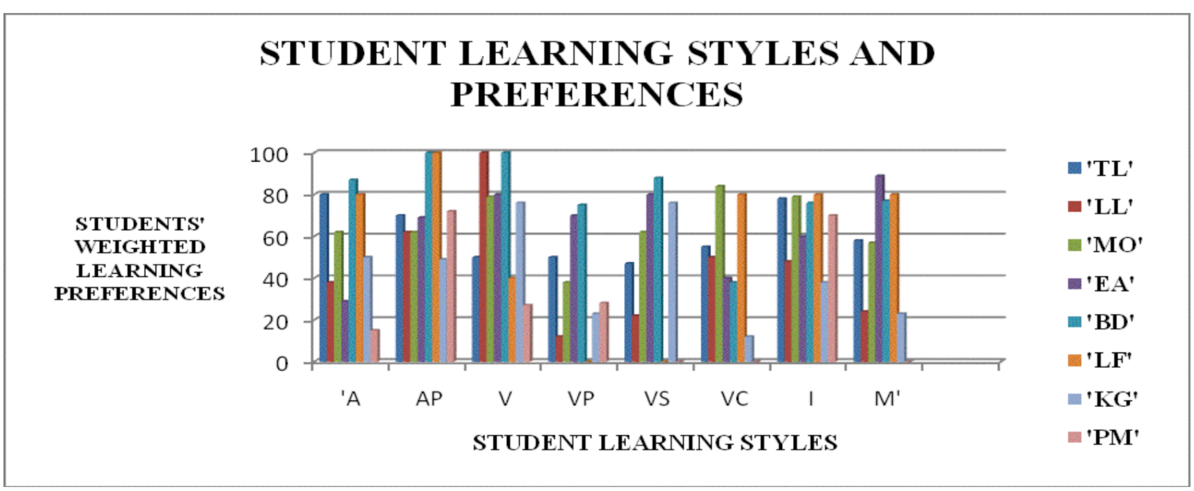
From the perspective of the brain, the most direct theory of learning styles might be one that leads us to evaluate students according to the types of sensory inputs provided and the motor outputs that they engage in within the educational setting (classrooms, labs, etc.). Some students learn best through reading text while another might have a stronger preference for representation of information in the form of spatial displays of information (e.g., neuroanatomy). Another student might benefit from the aural presentation of information rather than from reading. These differences can sometimes be dramatic.

In one neuroanatomy class at MIT that involved the presentation of literally hundreds of slides, approximately one out of every thirty five students did not take notes. When asked why, these students said that they could only really learn through listening. They recorded the lectures and listened to them once the same day as the class was given and then once before each test. Another example of learning style differences, even more dramatic, was one student who actually had to translate each slide into verbal text. Her reason was simply. "I can't learn very well from pictures!" These extreme examples only serve to emphasize that students have different strengths in any learning style that we might want to define.

Another learning style that we identified in classes at MIT involves what we called cognitive processing (Singer, D.A., Schneider G., Microsoft, iCampus Report, Massachusetts Institute of Technology, Cambridge, MA 2006). What this refers to is the learning style of students who seem to benefit more when they have the opportunity to ask questions or answer questions (Cognitive Processing) in class rather than just listening (Aural Monolog). The experience of listening and taking notes in a more rote method seems to benefit others much more.

Cognitive processing involves well-recognized areas of the nervous system, particularly the prefrontal cortex.   From this learning style perspective, over a period of two years, the learning styles of students within the classroom were assessed (Singer, D.A., Schneider, G, Microsoft, iCampus Report, Massachusetts Institute of Technology, Cambridge, MA 2006). Here is a typical example of what we found.

FIGURE 1



This figure describes a randomly chosen sample of the learning styles of eight students: A = Aural learning, that is, learning through simply listening, AP = Aural Processing, that is, learning through asking and answering questions, V = learning through reading, VP = Learning through answering written questions (homework!), VC = Learning through using color in taking notes or in looking at slides, I=Interpersonal learning, that is, learning through group work where the student can both help other students, learn from other students and interact with other students in spontaneous ways, M= Media and includes learning through the use of a variety of media, including videos, animation, etc.

The students' learning styles were assessed through a rigorous process. This included administering learning styles surveys twice, once at the beginning of the term and once at the end. Most students were also interviewed in order to cross validate their survey results, and, lastly, up to eight 5-minute observation periods were made of the students' in class. While such a comprehensive assessment is unusual, it was undertaken to insure the validity and reliability of the results.

It was clear that each student had a unique and preferred way of learning that she or he considered the most beneficial.

Regardless of how we might describe the learning style of a student, we must recognize that every student probably has some degree of ability in the use of any learning style. Because one student may have outstanding musical ability that does not mean that that student may not possess excellent ability in verbal reasoning, spatial reasoning or any other learning style we might describe. A complete lack of any given learning style probably would describe a rare anomaly and probably reflect a neurologically based pathology.

With regard to our distributed curve theory, it is likely that the relative abilities with respect to any learning style reflect a relatively normal distribution among students. It is also probably important to add a few additional points in order to consider the importance of learning styles in teaching. First, when given free choice and open opportunity, students will most likely adapt to their classes and their approach to learning based upon their preferred learning styles. Second, to the degree that students are given predetermined methods of learning, they will adapt with varying degrees of success or failure. The teaching style of any teacher is best suited for some and more of a struggle for others even if they achieve the same grades.

Abilities

We generally describe the term "abilities" as meaning some forms of intelligence. The well known Wechsler Intelligence Test probably best represents the way we have standardized intelligence. However, if we evaluate the ten subtests of the Wescler Intelligence test we find that they reflect very different abilities and consequently very different neural circuitry. For instance, among the subtests, there are such scales as vocabulary (rote memory), comprehension (of written material), digit span (short term aural memory, and block design (manipulation of cubes to match a specific pattern). As a result, as described here, no matter how we might define intelligence, we are really describing the different learning styles of students.

Performance Scores

As previously stated, each learning style is represented among a student body as a distribution of some sort. Every faculty member knows that some students do better than others even if we could control for the amount of effort that is put in. What is interesting is how the performance might vary when we evaluate the individual performance scores. Some students do better on projects, some on multiple choice tests, some on open-ended questions, some on participation, or presentation, some on invention and the application of what was learned to a new creation. If we evaluated our students on the performance scores we use, we would probably see that few students score at the same level on all measures when compared to the rest of their classmates. This both reflects the individual learning styles of each student and, as a result, an important variable to consider when we evaluate the effectiveness of any educational software product.

Teaching Styles

Teachers teach in different ways. Over several semesters we evaluated the teaching styles of fourteen professors at MIT. We wanted to observe a representative sample of categories that might describe different styles of teaching. For instance, some professors are almost pure lecturers. Others spend a significant amount of class time answering students' questions or asking questions. Some professors emphasize new material not available in the textbooks the students buy. Others emphasize review type teaching. Some use many slides and other media sources. Others do not. In addition, the basis for grading a student can vary widely among professors (Singer, D.A., Schneider, G, Microsoft, iCampus Report, Massachusetts Institute of Technology, Cambridge, MA, 2006).

FIGURE 2

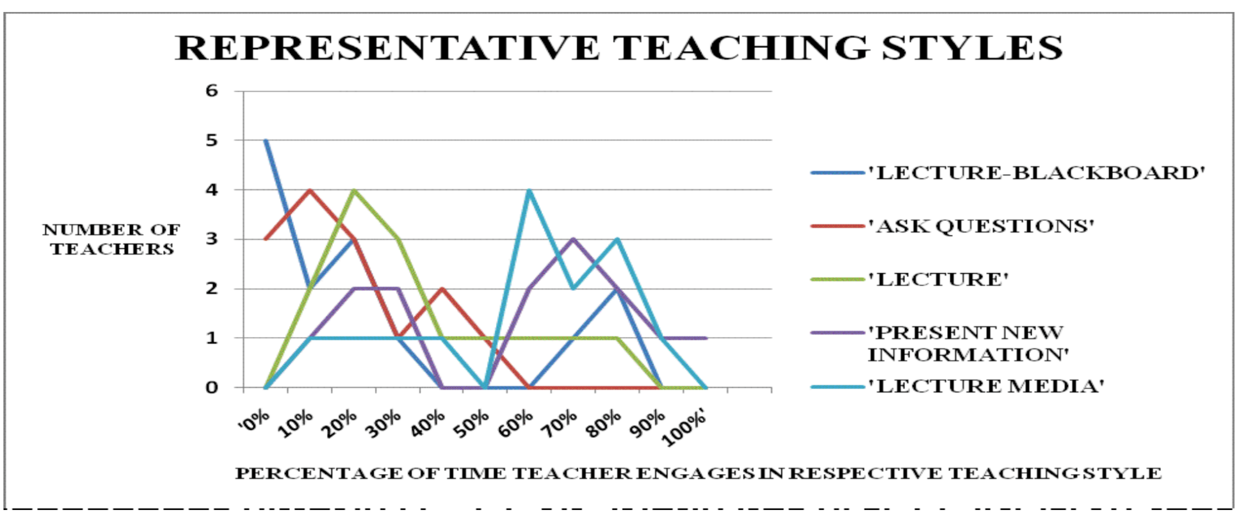


Figure 2 reflects the amount of time that different MIT professors spent engaging in the teaching styles shown. For instance, the amount of time professors spent asking students questions or answering questions varied between 0% and 50%. The presentation of material in the lecture-only format without complementary media or writing on the black (or white) board varied between 10% and 80%.

While this small sampling certainly cannot strongly support any specific scientific conclusions with regard to teaching styles, one result is clear. Professors can teach significantly differently. A very important point here is not that one teaching style might be better than another. However, based upon what has been described above, we can conclude that there will almost always be an advantage to some students and a disadvantage to others no matter what style of teaching is employed. These advantages or disadvantages can seem small as most students have all of the learning styles described to varying degrees and can adapt to the teaching styles offered. However, the result is essentially that some students with a different profile of learning styles may have to make a greater effort to learn the same material than other students of equal "ability" or potential. Or, perhaps, a given student will not do as well as a student of equal ability just because of the teaching styles used by the professor or the criteria upon which a grade is based.

When we consider what has been discussed so far, we can consider that the greater discordance between the students' learning styles and the teaching styles, the greater difficulty the student will have in learning the material. We could probably not expect the teacher to adapt to the ideal teaching style of every student. However, it may be possible that the use of educational technology can help ameliorate that problem.

Educational Technology

We can evaluate any educational technology and create a specific profile of what aspects of learning theory are used and what specific teaching styles are incorporated. By doing this, we have the potential to offer students methods of learning that can compensate for what might be lacking for them specifically in any course that they take. Whether the educational technology used would be accessible within their classroom with their laptop or desktop computer or accessible in their libraries or at home might be another question that needs to be addressed, but, nevertheless, the opportunity to have access to such technologies could only improve learning for a given student.

In Figure 3 below we show our evaluation of representative software products and a representative sampling of the range of teaching styles reflected in the software. This also includes some of the motivational and testing subsets we evaluated. What became evident was that the differences were sometimes very large.

FIGURE 3

DISTRIBUTION OF TEACHING STYLES AS SEEN IN VARIOUS EDUCATIONAL SOFTWARE PROGRAMS

ACADEMIC	
Aural – Visual/Text	0% - 50%
Aural – Visual/Spatial	0% -100%
Aural – Real world applications	0% - 50%
Visual only	0% - 100%
AFFECTIVE	
Aural/Positive Reinforcement	0% - 100%
Visual/Positive Reinforcement	0% - 100%
TESTING	
Fill-In (Recall)	0% - 25%
Multiple Choice (Recognition)	0% - 100%
Comprehension	0% - 75%
Hints	0% - 100%
Immediate short-term memory	0% - 100%
Delayed short-term memory	0% - 60%
Timed	0% - 100%

While there is not enough space here to correlate the representative teaching variables that we have selected to corresponding teaching styles of teachers and with the learning styles of students, suffice it to say that in an ideal world we would be able to interface the learning styles/abilities, teaching styles and educational technologies so that a learning environment could be created that reflects the optimum educational environment for students individually. For example, with an educational software product that emphasizes text in neuroanatomical or architectural descriptions, we would expect that students whose learning style strength includes reading and not spatial representation of information would benefit from this product. This would be even truer if the teaching style of the faculty member included an emphasis on pictorial slides.

One additional point should be made here. There would remain a question as to whether an educational software product should be used by a student to augment the student's strengths or assist in relative weaknesses. At the university level, it would probably be the decision of the student. In the elementary grades this would be a very important question to be addressed since the child's brain is much more malleable and can benefit from both enrichment and remediation.

Conclusion: Assessment and Application

The use of educational technology is here to stay. There now exist an estimated 30,000 to 40,000 educational software and hardware products to choose from. There is no reason to avoid undertaking more empirical assessment efforts in order to determine how they might best be used for students. The hit-and-miss approach that now predominates wastes time, money and effort. In addition, the results are questionable. To ameliorate this, we must apply some standard scientific controls. Educational technologies offer us the opportunity to address the unique learning styles of every student. In order to do this, we should and can incorporate student learning styles, teaching styles, specific performance scores, and the learning styles reflected in the actual software or hardware product.

While it may seem impractical, unobtainable and maybe even too futuristic to create a learning environment that incorporates these variables, it should not be. Every year we already spend many billions of dollars to develop, sell and incorporate educational technologies in education. Billions more are spent trying to develop new learning environments and teaching methods to help students.

At the rate that we are uncovering the workings of our nervous systems, and as we recognize that it is an inescapable truth that each child has a unique set of learning styles, there is no reason that educational hardware and particularly educational software cannot be created to customize education for every student.

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