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AUTHOR	De Laurentiis, E. C.
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ABSTRACT

There is a lot of educational software on the market, but little of it can be said to be revolutionary. Despite all the talk about education and computers, the educational software revolution has yet to begin. All educational software can be placed in categories of games (edutainment), simulations, reference software, and tutorials. Choosing excellent software is also complicated by the buzzwords that current advertisers use, including multimedia, edutainment, interactivity, CD-ROM, and graphics. Beyond these buzzwords, there are some real criteria for excellent software as follows: (1) symbolic graphics; (2) adaptability; (3) student control; (4) the medium matched to the content; (5) relational content; (6) hierarchy of instruction; (7) thorough treatment of the content; (8) knowledge of results (feedback); and (9) predictable results. The production of excellent software requires a technology (in the sense of techniques or methods, rather than devices) that includes knowledge representation, instructional design, and media application. (SLD)

How to Recognize Excellent Educational Software

by

E. C. De Laurentiis

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Educational Software and Education

Although the first application of computers was in mathematics, it didn't take long for people to start dreaming of the day when computers would be used for education. The trend towards programmed learning in the early 60's, and the development of mechanical teaching machines, led people to think of computers as potential teaching machines. Yet, in the 60s, computers were too cumbersome and too expensive to be practical for educational purposes. It wasn't until 1976, with the development of the first microcomputers, that the use of computers for education became feasible. Since then, computers have become more powerful, and prices have dropped to commodity levels. Add-ons, such as software, now increase the perceived value of computer purchases. Educational software, on the other hand, has not been evolving as rapidly. While there is a lot of educational software on the market, very little of it can be said to be revolutionary. Despite all the talk about education and computers, the educational software revolution has yet to begin.

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How Computers are Used in Education Today

There are thousands of educational software products on the market. Publishers attempt to position their products according to specific features, such as whether the product has graphics. Many of these distinctions confuse the market, and have little to do with educational value. The following taxonomy is meant to clarify the distinctions in educational software. All educational software can be placed in the following four categories:

1- Games (or Edutainment)

Educational computer games are rote-learning, drill and practice programs, in the guise of entertainment. Drill and practice activities are useful for skill reinforcement, but they are not instructive in themselves. There is very little new learning that occurs during a game. Any learning that may occur is incidental. For example, when a student blasts the correct answer in a math problem from descending alien spacecraft, he or she hasn't learned how to add or multiply. In this case, the student has just practiced a skill that may have been learned somewhere else.

2- Simulations

Simulations are programs that allow students to play a role in an imaginary situation. Original computer simulations were patterned after dungeon and dragon board games, where players take on the personality of a character in a story. Many current computer simulations are similar, except that the student is often placed in historically or geographically accurate settings, and the story is interactive. In these literary simulations students take on the role of both screenwriter and director. Students exercise their literary skills with these simulations. Another type of simulation, the case-study, is used to simulate business or societal interactions. These are used to help students learn about societal situations without the danger or stress that the actual situation may entail. For example, in a stock market simulation, students could safely lose millions of dollars. Or, in a rape crisis preparatory course, a computer simulation could prepare a woman to protect herself. Mechanical simulators, such as flight simulators, allow students to perfect a skill before they endanger theirs, or some one else's, life. In the future, virtual reality hardware will make all simulations seem more realistic. With this hardware, students will be able to experience simulated three-dimensional worlds, interacting with imaginary characters. Anyone familiar with the "holodeck" on the *Star Trek The Next Generation* television show is familiar with the aspiration of virtual reality. The disadvantage of simulations is that they do not impart the knowledge or skill that students need to succeed in the simulation, or in real life. While simulations are useful for providing experience, they cannot provide the requisite skills or knowledge to succeed in a similar challenge.

3- Reference Software

Reference software are the electronic equivalent of encyclopedias. Today's electronic reference products feature animation, sound, and digital video, and are often distributed on CD-ROMs[1]. Their multimedia features improve upon paper-based encyclopedias, yet they suffer from difficult-to-use interfaces that are more likely to frustrate users than help them find information. Many publishers market reference software as if they were instructional, neglecting the need for a curriculum. They are capitalizing on the multimedia bandwagon. While reference products are important for learning, education requires a curriculum. Of course, learning does occur in exploratory environments such as encyclopedias, but a curriculum is still paramount. A curriculum is the educational strategy that increases the probability that learning will occur. Reference software suffers from the lack of a curriculum.

4- Tutorials

Many software tutorials are nothing more than page-turning, computerized books, that attempt to feed students information. They exhibit many of the worst qualities of the old mechanical programmed learning systems. They are linear, rigid, and do not adapt to the needs of the student. Educational software should generate new exercises based on students' needs. Few do so. In a weak attempt at adaptability, many software tutorials allow students to select several different levels of difficulty. This is inadequate, for the analysis should be at a more detailed level. Excellent educational software would customize individual lessons to meet the specific learning requirements of each student. It would evaluate the student on a concept-by-concept basis. Educational tutorials should adapt lessons to a learner's learning style, and generate activities to take a learner's previous abilities into consideration. Most importantly, excellent tutorials would embody a detailed curriculum.

1. CD-ROM stands for Compact Disk Read Only Memory. They are similar to audio compact disks, except that a special CD-ROM reader attached to a computer is required to read them. Their advantage is that they hold 500 times more information than conventional floppy disks.

Buzz Words that Advertisers Use and Their Meaning

The computer world is replete with buzzwords. This hyperbole tells you what people *think* is important. It does not indicate what is genuinely important. It is important to dispel the media's emphasis on these buzzwords because they are not as important as they are made out to be. Major buzzwords that you will hear in relationship to computers in education are: multimedia, edutainment, interactivity, CD-ROM, and graphics. Following is a description of what these words really mean.

Multimedia

Multimedia is the ability to display text, graphics, computer animation, and video, on a computer screen with audio. From a purely technical point of view, this ability is revolutionary. Only recently has computer hardware and software been sophisticated enough to exhibit these features. This is now possible because of recent advances in microprocessor speed and in information compression techniques. It is leading to the convergence of television and computers.

While technically exciting, multimedia does not automatically lead to better educational software. Incorporating these different attributes is only the surface of education and has little to do with the essence of a curriculum. Learning occurs when the surface structure of a curriculum (i.e. activities, graphics, sound, text, etc.) corresponds to its deep structure (i.e. the structure of the knowledge domain). Educational software that uses many media, may be exciting on the surface, but unless developed with the deep structure of knowledge in mind, will not be instructional.

Edutainment

Edutainment refers to software products that purport to teach in an entertaining way. Often, these products incorporate video-game like activities. As mentioned earlier, games have a reinforcing role, but not an instructive one.

Interactivity

Many publishers claim to have interactive software, yet few people know what that means. In a conversation, if someone you are speaking to responds to what you are saying – that is interactivity. On the other hand, if you say "How do you do?", and the person responds "It is raining in Cincinnati" – that is not interactivity. Most educational computer software is like the latter. It pretends to interactivity, but often fails miserably. Interactive educational software responds to the student's learning needs. It gives the student freedom to explore, and the power to choose what he or she will learn, or how he or she will learn it. Interactive educational software will also evaluate students' knowledge at a detailed, deep level, and make new explanations or activities available hat will help students understand the topic. More advanced interactive educational software will ask questions to determine what students know, or don't know, and generate original activities to fill the gaps in the student's knowledge or skill.

CD-ROM

CD-ROM stands for Compact Disk Read Only Memory. It is a relatively new technology for storing information. Rather than using magnetized bits of information, as in hard disk drives, CD-ROMs store information as microscopic holes that are read by a laser beam. The advantage of this medium, is that on a platter only 5.25" in diameter, it is possible to store 500 million bytes of information. That is the equivalent of 357 high density 3.5" floppy disks, or 250,000 single-spaced typed pages. The other advantage of CD-ROMs is that they are very inexpensive to reproduce. Because of the magnitude of storage, and the low cost of reproduction, the distribution of large amounts of information on CD-ROMs is very feasible. Thus, it is practical to have an encyclopedia of information on one disk. But CD-ROM is still only a storage medium. Advertisers would like people to think that CD-ROM products are magical. It is easier to place 500 megabytes of nonsense on a CD-ROM, than it is to have excellent educational content.

Graphics

When people refer to the use of graphics on computers, they may mean any of the following: illustrations, photographic stills, cartoon-like animations, or digital video. Educational software publishers, like educational book publishers, often fall into the trap of producing gratuitous graphics – graphics that are irrelevant to the understanding of the concept being taught. Many educational software designers think that the purpose of graphics is to amuse and entertain the student as a comic or visual relief from learning. They underestimate the intrinsically motivating aspect of learning. Graphics should enhance the learning process by clarifying the topic. Humorous graphics can be used to teach by telling a story. As visual beings, graphics have a powerful effect, but there is no need for distraction and irrelevance in a learning environment.

What to Look for In Excellent Educational Software

Having described a taxonomy of educational software, and dispelled some notions behind industry buzzwords, I will now outline the criteria for excellent educational software.

Symbolic Graphics

Graphics should be symbolic of, or represent, the topic being taught. For example, what is relative motion? Relative motion can be defined as the motion that one perceives relative to one's position or movement. In textual form, this is a difficult concept to understand. Animation could be used to clarify the concept. The animation could be as follows. "Imagine a very long passenger train. The train is moving from left to right, while you are stationary. Inside the train, you can see that someone is walking from right to left at exactly the same speed that the train is moving from left to right. What you perceive is a moving train and the person inside is stationary relative to your position. That is one example of relative motion." Animation could have clarified in an instant what just took seventy words to describe (and perhaps not as effectively as the animation would have). Graphics can clarify many topics that otherwise would require much visual imagination to understand. Albert Einstein once explained his genius as the ability to visualize the nature of universal laws. For example, he explained gravity in the following way. He visualized the universe as a taut plane (such as a table cloth being held at its four corners), and bodies with mass, such as planets, as objects lying on the plane. The greater the mass, the more of an indentation it would form on the plane. Imagine an orange on this table cloth. It would form a deep indentation. A small marble would not form as much of an indentation, therefore it would roll towards the orange. The orange, having greater mass, has more gravity than the marble. Another example of the import role that graphic imagery plays in understanding, is in the story of James Watson' and Francis Crick' struggle to discover the structure of the DNA molecule. They were discussing their problem, and began to visualize the DNA structure as a ladder. Unfortunately, that structure posed some problems that were not evidenced by the data. It was not until they visualized twisting this ladder like a corkscrew, that they were able to explain how the DNA molecule is built.

Graphics is a powerful teaching tool. It can be used to explain, and to stimulate. It is important that the graphics are complimentary to what is being taught. Irrelevant graphics are nothing more than a distraction which interferes with learning.

Adaptability

Educational computer software should adapt itself to the student. This means taking the student's current knowledge and skills into account when presenting the student with activities, information, or problems. Any good teacher who has the time, would do this. First, the computer must be able to evaluate students' current competence. Second, it must be able to generate new activities based on this evaluation.

> A curriculum is the educational strategy that increases the probability that learning will occur.

Current educational software often provides the ability to change levels of difficulty. This is inadequate as an educational strategy because these levels of difficulty are often too coarse to have any meaning. The diagnostic process must be more detailed, operating at a micro level. At a micro level, students' abilities are evaluated on a concept by concept basis. This is one of the shining promises of educational computer software, that few publishers have attempted to achieve. Books cannot provide this kind of diagnostic capability, and adaptability, because they cannot incorporate analytical intelligence. Many teachers have the ability, but not the time. For this adaptability to be effective, the computer must evaluate the student at a highly detailed level. For example, when a student cannot answer the question, "What is the sum of 2+2", the diagnostician ought to consider several possibilities:

1- Does the student not understand the meaning of the word "sum"?
2- Does the student not know the meaning of the symbol "+"?
3- Does the student not know how to count?

4- Has the student not memorized the answer to this problem?

Depending on the answer to these questions, different remedial solutions would be appropriate. For example, the computer could define the word "sum" or the symbol "+", or provide exercises to help the student learn how to count. Even such a simple problem requires detailed analysis. Good teachers do this automatically, but most educational computer software designers don't even consider the need for this level of diagnosis.

Student Control

Much of our educational system assumes that students need to be coerced into learning. Given the conditions that learning often takes place, that is no surprise. Since so much of classroom experience is geared towards pandering to the lowest common denominator, and because so little of education takes individual difference into account, it is no wonder that students tune out. When education is individualized and effective, you cannot tear students away from their studies. Learning is intrinsically motivating to humans. When learning is a joy, we want more of it. Learning reinforces studying. That is why student control is so important. A reinforced learner wants to study. His or her hunger for knowledge is impatient and insatiable. It does not want to wait for a designer's idea of when the next topic should be covered. Learning, in fact, is not a linear, ordered progression. It is more like a spiral. At first, we become familiar with the surface of a topic, then we learn about related topics, and we return to learn more about the first topic. Every time we return to a topic, the body of knowledge becomes clearer. We develop relationships to other things that we know, or that we have subsequently learned. We form associations that makes the information pertinent. Giving students control of their learning, allows them to form these important associations. Educational software should provide access to all of the knowledge and activities it contains under student control. Thus, students will be able to form their own knowledge schemas according to their readiness and receptivity to greater detail in a knowledge domain.

While technically exciting, multimedia does not automatically lead to better educational software.

The Medium Matched to the Content

We are accustomed to think of media as the device we use. Media is not the device, but rather the means by which information is presented. For example, it is commonplace to think of television as a medium. The medium is actually moving pictures. The television set is just the device used to present the moving pictures. Similarly, books are not a medium. The medium is prose. Our society has moved from an emphasis on industrial goods, to an emphasis on information goods. Similarly, we must look upon media, not as the physical item upon which the information is presented (paper, television, photographic film), but rather as the way in which the information is represented (prose, illustrations, moving pictures, sound). As I detailed earlier, the multimedia capabilities of many of today's computers allows us to mix prose, illustrations, moving pictures, and sound in one device. This covers every educational medium except for those which involve direct human contact and conversation. This makes the computer a very flexible educational device.

The medium must be chosen carefully to suit the content. For example, while it may be instructional to depict the concept of acceleration in physics with animated graphics, it is also important to describe it with prose and to represent the relationship of force and acceleration with a mathematical formula. The medium that is used to teach a particular concept ought to depend upon the level of detail that the student needs to learn. Educational software should use different media in the presentation of a topic depending on what the student is learning, as well as on the educational objectives for a particular topic.

Relational Content

Educational content should be presented in such a way that the association between concepts is made explicit. It should also be possible for students to explore these associations. This is important for learning because we learn best when we can associate what we have learned to something we already know. When we have made the association between what we know, and what we are learning, the new concepts develop greater clarity and relevance. That aha! experience that occurs when an idea is finally crystal clear, comes from our having integrated the new knowledge into the associative mesh of concepts that forms our knowledge of the world. Our knowledge of the world, and all bodies of knowledge, consist of these meshes of interlinked concepts. The goal of education is to have students integrate the mesh of concepts which forms a particular body of knowledge, with their own personal and individualized mesh of concepts, that is their individualized knowledge of the world. Excellent educational software will make explicit the associations in the body of knowledge that is being taught. This simplifies the student's task of integrating this new body of knowledge into his or her own mesh of concepts. The software should also make it possible for the student to explore the associations, therefore enhancing his or her own mesh of concepts, and building an individualized representation of the world.

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Hierarchy of Instruction

While knowledge is an associative mesh, all knowledge or skills presuppose some other knowledge or skill. A baby speaks because verbal communication is "hard-wired" into human beings. The penchant for speaking exists at birth. You cannot learn how to multiply, unless you can count. You cannot appreciate Shakespeare's Henry IV, unless you also consider the historical context in which it was written, and you will not laugh at a joke, unless you understand the culture in which the joke was written. There are specific and definable prerequisites for every skill or knowledge. Excellent educational software will evaluate whether the learner has the prerequisite knowledge for a concept and help to fill the gap.

Thorough Treatment of the Content

Of all the ills of bad education, one of the most ubiquitous is that the content is often incomplete. Very few authors either have the time, the inclination, or the techniques, to prevent this. Incomplete content is the main reason why learning is often so difficult. For example, a teacher might describe the formula for acceleration, forgetting to define acceleration. Such an omission can be disastrous because the student ends up memorizing the formula without ever understanding what it really means. The student has learned by rote, and will never be able to apply this information in a creative, problem solving, situation. This obstacle can happen in any field, not just in mathematics. For example, students who know that in 1863 the federal government did not control all areas of America, realize that the Emancipation Proclamation only pertained to rebellious areas under the Confederacy. The Emancipation Proclamation itself, did not free any slaves. Omitting the political details has led many people to believe otherwise.

Thorough treatment of the content means that such information holes are resolved. Students cannot be expected to be clairvoyant, and to fill the gaps themselves. Besides, it would not be until much experience that students would know enough to realize that some information was missing. Education should facilitate the learning process, not create artificial "challenges" by leaving out important details. This amounts to malpractice, and serves no purpose other than to artificially lengthen the learning process. The true challenge to learning should be how to use current knowledge to discover more about the universe, and to extend the range of human enterprise. Those are the puzzles worth exploring. Incomplete content, on the other hand, is nothing more than sloppy teaching.

Knowledge of Results (or Feedback)

It was Norbert Wiener, the father of cybernetics[2], who first described the importance of knowledge of results as a means of reaching a goal. A thermostat, for example, functions by feedback. If the result of the thermostat reading is that it is too cold, then the furnace is turned on. If the result of the thermostat test is that it is too warm, then the furnace is shut down. In learning, feedback acts as a regulator and a reinforcer. As a regulator, frequent and immediate feedback tells the student what knowledge or skills he or she needs to improve. The power of this is not to be underestimated. Frequent and immediate feedback serves to focus learning activities, and to result in positive behavior changes. The result is faster and greater success in learning. As a reinforcer, knowledge of success is an intrinsic reward, thus increasing the student's motivation to learn. The more immediate, and the more detailed the feedback, the greater the effect as a reinforcer. Excellent computer software would evaluate student performance, and provide immediate, clear, feedback. Furthermore, it would use this knowledge of results to shape the learning activities, and to strengthen a student's weak areas. Computers are the only devices that can deliver the immediate analysis, and feedback, for knowledge of results to be feasible.

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Predictable Results

Excellent educational software will give predictable learning results. The student will learn what was intended for the student to learn. The associative mesh of concepts that the software contains will have been integrated into the student's own associative mesh. Does this mean that students become automatons who parrot someone else's words? Not at all. How a student integrates knowledge, and uses it, is very personal. Any particular student's use of new knowledge or skills is unpredictable because it is dependent on the student's previous learning experiences. The goal of excellent educational software is to provide the student with a rich learning environment that is sensitive to individual differences in learning. This increases the probability that learning will occur.

Why Most Educational Materials Do Not Meet These Standards

I have described many criteria to create excellent learning environments with computers. Many of these criteria apply to good education no matter what the learning device. Teachers can practice these principles in a classroom, or they can be applied by an educational software designer. But can anyone attain these standards? Those who come close to doing so are the exception, rather than the rule. It takes a particularly gifted curriculum designer to achieve the educational results we seek. To do so with computers is even more difficult because of the inherent technical challenges. The production of exceptional educational materials, in large quantities, without relying on scarce prodigies, is possible. To do so requires a technology[3] of educational software development. I have been

2. The study of communication systems in living organisms and machines.

3. Technology is being used to mean techniques or methods, rather than devices.

developing such a technology for the last twelve years. It consists of three basic sub-technologies:

1- Knowledge Representation
2- Instructional Design
3- Media Application.

Using these three basic sub-technologies (or K.I.M.) it is possible to develop any educational activity, incorporating all of the criteria previously described. More importantly, the process can be taught and is replicable.

Conclusion

Despite its promise, and the vision of many futurists, technology has yet to make its mark on education. It is my conviction, that if we do not apply a technology of educational software development, computers will be relegated to a trivial role in education.