

Creating a New Environment for Learning Math and Science

Creating the Future IDEAL Classroom

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IDEAL: Intention Driven Environment for Active Learning

Introduction

According to the recently published report, "The Silent Crisis, " from BEST, a three-year partnership of government, industry and academic leaders that is focusing on Building Engineering and Science Talent, there is a critical and growing demand for skilled technologists in the United States that cannot be met by existing education strategies. For the United States to maintain its leadership in the information revolution, the teaching of math and science must be treated as a necessity, not a luxury. Many of working engineers and scientists who created the information revolution are close to retirement and there are not enough qualified young people available to step into their positions. Not only is the total college-age population much smaller than a few decades ago; the percentage of students majoring in math, physics, chemistry, computer science and engineering is shrinking as they shift to other non-technical majors. As overseas countries become competitive in technological innovation, industry in the United States cannot rely on the current practice of attracting foreign talent to make up the shortfall. We must revitalize the education system and attract more students into math and science classes at all levels of the educational process.

Correcting this problem will be a major challenge since it is not just a matter of having a too few students, there is also a shortage of qualified, inspirational teachers. We will need to develop solutions that simultaneously address the needs of both the students and the teachers.

We believe the key to achieving this is to create a radically new learning environment that takes both the teacher and the students on an exciting voyage of discovery in which knowledge and experience are seamlessly blended and delivered at a rate determined by the individual learner. Video game developers long ago recognized that children and young adults learn by doing and playing. Our challenge is to create learning environments that are as immersive as video games while going beyond their virtual nature. This requires a drastically different approach from what is being done today.

Computers have been installed in schools for almost two decades with the promise they would revolutionize education but, all too often, children spend an inordinate amount of time learning how to use classroom computers, and too little time focusing on what they are supposed to be learning. This is not only a sad outcome; it is a dreadful waste of resources and time!

Driven by the right sort of software, and connected to the right types of resource, computers can become fantastic windows onto anything in the universe. They could become microscopes to look at the building blocks of nature and the elements of life; telescopes to look at anything from just across the road to the

edges of the universe; or time machines for journeying back through the history of man or the evolution of the universe or exploring what the future might hold. James Burke, through his "Connections" column in Scientific American and his TV series of the same name, demonstrated how much more memorable things become when you see how one event leads to another, and are then able to understand the dependencies. With all the computers with Internet connections that are already in schools, why isn't this already happening? The simple answer is that today's computers get in the way. They are anything but intuitive, and the windows they provide are cluttered and murky.

The problems inherent in trying to use conventional computers and operating systems to build intuitive, interactive learning environments are deeply rooted and too big to be eliminated by simply rearranging existing resources. No matter what the proponents of conventional computing strategies may say or do, the underlying model is flawed and can't be fixed by adding more layers of software.

So, what can we do? We must first look beyond the current practice of using computers designed for offices or homes. They are still too difficult to set up and use in educational applications and they employ operating systems and data structures that do not provide the necessary flexibility and reliability. Second, we must look at how information is encoded, stored, searched, browsed and retrieved; much of the knowledge required to revitalize education exists but has been ignored through the focus on hardware rather than the desired result: an educated human. Third, the quality of educational information is strained; the best teachers are often compelled to use dubious textbooks, where the IDEAL system can offer them access to the most lucid minds available.

The computer industry adds another layer of complexity to this situation. The profitability of this industry is based on short-term planning, marketing that compels user's to lust for speed, and version obsolescence. Software and hardware companies play a constant game of leapfrog that makes it necessary for consumers to upgrade regularly. While many schools already have classroom computers, they rarely have the resources for constant upgrades so they find themselves on a resource-draining treadmill driven by obsolescence. Faced by ever increasing complexity and incompatibilities, teachers are reluctant to invest time and effort into preparing computer-based class materials when the computers keep changing and there is no assurance that materials can be reused with future classes. The overall result is that most of the computers currently in schools are poorly matched to educational needs, under utilized, and outdated.

Archimedes at Stanford has developed new computer access technologies that have the potential to revolutionize the use of computers in education. Students can be immersed in highly interactive, media-rich, learning environments in which:

1. They are able to move seamlessly between live or computer-based lessons, with consistent and familiar access to stored knowledge.
2. They can learn how things work through simulations and practical hands-on experimentation.

There is a twofold goal for this system: The first is to build a solid understanding of underlying concepts and theories by presenting clearly defined

concepts, underlying theories, examples of applications, mathematical visualization tools, and simulations. The second is to reinforce the learning experience through simultaneous hands-on practical experimentation, simulations and mathematical verification. While these learning strategies could be applied to almost any field of education, we believe quantifiable results and an urgent and widely recognized critical need make physics and mathematics an ideal choice for proving this new concept.

A New Approach to Educational Computer Systems

We are proposing a new computer system specifically designed for educational use in which students and teachers are immersed in a collaborative learning environment in which each participant has a personal interface matched to individual needs and preferences, and independent of the underlying computer systems and the applications that are being used. Specialized experimental apparatus and measurement modules can be added in a plug and play fashion to match particular learning activities without disturbing any of the user interfaces.

These capabilities are made possible by our new ***"Intention Driven System" (IDS)*** that redefines the ways in which people can interact with computer based devices. The GUI interfaces commonly used on personal computers present users with a smorgasbord of icons, menus and choice boxes from which the necessary commands must be selected in the correct order to perform a desired task. The IDS makes computers easier to use by eliminating the need for users to know the detailed steps involved in performing each task. To get a feel for the significance of this, think of what is involved in starting the engine in a modern car compared to doing the same thing in an early vintage car. Today, it is very straightforward, we turn the ignition key and the engine starts. In a vintage car there are many steps that must be performed in certain ways and in the correct order: make sure the hand break is on and the gears are in neutral, set the choke based on air temperature and altitude, set the hand throttle to a fast idle, advance the spark, get out of the car, insert the cranking handle in the front of the engine, grasp the handle of the crank properly so that you won't break your thumb if the engine backfires, carefully turn over the engine to judge the compression stroke, crank the engine until it starts, remove and stow the crank handle, climb back into the car and adjust the controls over a period of time until the engine is running smoothly. The contrast between IDS and contemporary GUI computer interfaces is similarly striking. With IDS the user only needs to say or type a command in natural language or make a gesture and the system will identify and perform an intended task or sequence of tasks.

Figure 1 shows how the IDS deduces user intent and translates that intent into commands that instruct the computer to perform the functions necessary for completing the intended task. The target device can be any type of computer or appliance. If the target device is a TV, for instance, the user can control everything about the TV by giving commands such as "turn on the tv," "select channel 28," and so on. Commands like this are fine if people remember what to say and different people know to which words were chosen by the designers to represent each task

Experience has taught us, however, that people do not like memorizing scripts that specify what to say, and different people do not necessarily call things by the same name. A TV, for example, can also be called a television, television set, TV set, tele, idiot box, boob tube, and so on. An interface must be able to correctly recognize all of the names that apply to each device or function and all of the ways for using those names in meaningful commands. For example, the IDS will correctly interpret as "TV on" commands such as: "please turn on the tele," "I want to turn on the television set," or "I would like to watch TV now." The output of the IDS is not limited to single commands. A single command can initiate a whole sequence of interrelated tasks.

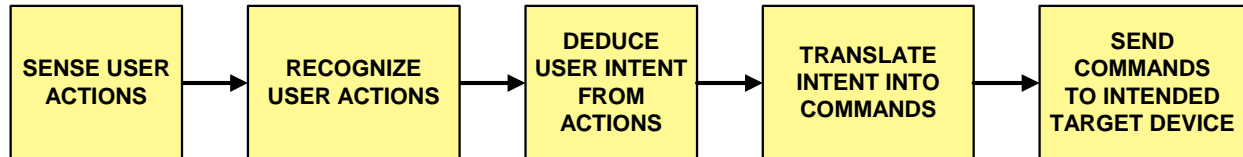


Figure 1. Functions Performed by an Intention Driven System (IDS)

In the learning environment that we envisage, computers are just one of many devices that must be controlled by the students and teachers.

- What if a teacher could use intuitive voice and gestural commands to search for, and load selected video clips onto her tablet computer, display them on the main classroom screen using a hand gesture, toss them with a gesture to a student's wireless handheld device, and edit them by dragging and dropping using head and eye movements?
- What if a student could control a microscope by voice commands, send the image to her tablet computer, edit the image with speech and pointing commands, flick it with a gesture to her neighbor's wireless handheld device, and drag down a relevant simulation and animated image from the main screen using a hand gesture?
- What if a student could interact with an electronics circuit by saying commands like: "read the DC voltage on pin six of the op-amp," "show me the frequency spectrum on pin six of the filter chip," or "set the audio oscillator to one Kilo Hertz"?

This is precisely what IDS enables us to do. What would otherwise require long detailed lists of step-by-step instructions are reduced to a simple sentence expressing the user's intention. The student can focus on what they are doing and why rather than how. With carefully structured IDS learning environments, we believe students will be able to focus on the message rather than the artifacts of the presentation. Teachers will be able to craft the messages to provide the most effective mode of delivery, remembering the old adage, "what I hear, I forget; what I see, I remember; what I do, I understand."

Figure 2 shows a block diagram of the IDS educational environment configured for teaching mathematics and physics. In conjunction with the SUMMIT

Project at Stanford Medical School, we have chosen the name IDEAL for Intention Driven Environment for Active Learning.

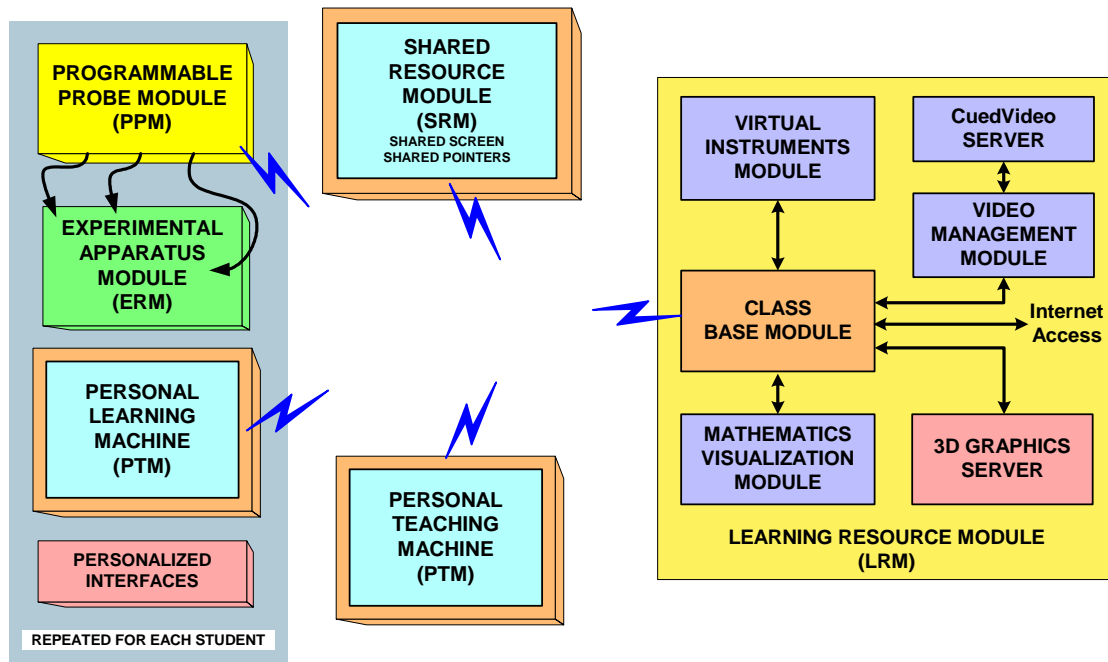


Figure 2. Block Schematic of the IDEAL Educational Computer System

An IDEAL classroom will be much less intimidating than contemporary computer-equipped classrooms. Apart from shared resources such as screens and printers, and personal tablets, all of the classroom computer system components will be in a closet or a back room and effectively invisible to the students and teacher. Fixed resources are wired directly to the classroom computer system and portable equipment such as the tablet computers used by the teacher and students and the student experimental apparatus are connected wirelessly. The wireless system is fully automatic and not at all like Email or conventional networking. Information can be passed from one person to another using simple human language commands or gestures. The focus is on providing what the people need in order to behave naturally, not on what the machinery needs to do. Where necessary, IDS automatically supports additional interaction modalities to accommodate the special needs of students and teachers with disabilities.

Next Steps

The Archimedes Project has devoted more than a decade to creating special interfaces for people with diminished capacities due to disability and aging. In the process, we were surprised to find fully fit people calling us, demanding those exact same interfaces. It appears that in the process of building devices individuals with disabilities, we were building devices for all.

It is time to begin using these enabling technologies to eliminate man-made disabling situations caused by contemporary personal computers. We have already developed proof-of-concept prototypes of the building blocks that make the IDEAL classroom feasible. Now we need to build an IDEAL classroom and test it with real students and teachers working with real learning resources. We have identified many different individuals and organizations that can, and want to contribute to creating the components and resource materials that will be necessary to make wide deployment possible. When we describe the system to teachers, their first question is "when can we have it?"

- The need for more science, mathematics and engineering students is clear.
- The need to provide better support for teachers is clear.
- The failure of contemporary classroom computers is clear.
- The potential benefits of engaging students in exciting learning environments are clear.
- The building blocks for building an IDEAL classroom have been developed.
- There will be huge commercial possibilities for companies as standard products emerge.
- Financial support is required to get the process started.

Additional information

For copies of a more detailed proposal that includes reports and papers used in the preparation of this document, or if you see an opportunity for collaboration, or support, please E-mail Sandy Gabrielli, Archimedes Hawaii at:

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