

# Reflections on TICCIT | C. Victor Bunderson

This article presents the early experiences of the author and his colleagues on the courseware development team for the TICCIT computer-aided instruction system. It reviews the history of TICCIT using words of that time, and then assays to explain lessons learned during and since TICCIT times in three main areas: (1) learner control—the high goals and ideals held out for this concept and their difficulty of attainment; (2) progress maps culminating in mastery assessments—use of progress maps with navigation based on well-measured progress information; and (3) differentiated roles and technology integration (how design experiments using differentiated staffing models can serve as a replacement for premature evaluations and can lead to attainment of some of the hoped-for high expectations for TICCIT and other innovations in what CAI has become).

These three areas were selected to capture some of the essential issues that drove the early TICCIT project and that remain problematic today.

## Some History

In the October 1971 the MITRE Corporation, partnering with the University of Texas at Austin (UT Austin) CAI lab and Brigham Young University (BYU), submitted a proposal for just under \$5,000,000. TICCIT (Time-Shared, Interactive, Computer-Controlled Information Television) was based on innovative concepts in hardware, software, courseware, and implementation and was designed to produce a “Market Success for CAI.”

It is interesting to look back to those heady times when this proposal was funded, times when \$5,000,000 went a

lot further. TICCIT and PLATO were the two large projects in a major \$10 million initiative of the National Science Foundation’s Technology Innovations Group, under the leadership of Arthur Melmed. It was an NSF effort to jump-start CAI, after some promising beginnings at the Illinois Plato Lab and the UT Austin CAI Lab, which had both received prior NSF funding. With other funding these labs had attracted, they were both positioned to undertake these serious efforts. Now, thirty-six years after that first TICCIT proposal was funded, it is instructive to look back at those days and consider what was accomplished. Also, it is sobering to remember what dreams and ideals remain, elusive, apparently just beyond our grasp,

dancing away to the next decade and then the next, calling on another generation to try again. One must have a certain wry humor to view the overconfidence, even hubris, of those days, and to temper the accomplishments with the recognition of problems that remain unsolved.

One way to summarize TICCIT is to say that it was a synthesis of the contributions of three main groups—the systems engineering and project management expertise of MITRE Corporation, the CAI learner-controlled courseware technology and team production know-how of Victor Bunderson and his colleagues at the University of Texas CAI lab, and the instructional theories and design procedures of David Merrill and colleagues at BYU. The hardware itself, as well as the software and courseware, embodied what became known as Merrill's Component Display Theory of Instruction. MITRE's disciplines for engineering and management of innovative system solutions permitted it to use these instructional concepts, rather than dictate system constraints to a system designed for instruction should be built. Also, blended in was the courseware team's insistence on empiricism mixed with theory and with a commitment to the individual learner in creating the interface between the learner and the system. The centerpiece was giving the learner control of that interface.

In that 1971 proposal, some interesting claims were made, in several key areas, the system, the courseware, and the market. The bullet points that follow are selected from a longer list in the proposal's executive summary, and are quoted exactly except for one or two minor paraphrases (MITRE, 1971, p. i):

### **The System**

- Mass dissemination of CAI has been inhibited by the high cost of student terminals, computer hardware, and courseware.
- TICCIT has solved the hardware cost problem through the imaginative use of commercial television technology and low-cost/high performance minicomputers.
- The TICCIT terminal (at one-tenth the cost of the nearest equivalent CAI terminal) is able to deliver instructional movies, plus interactive computer-delivered graphics, voice, and text.
- Terminal costs will be very low, ranging from a low of 10 cents in future home CATV applications to perhaps \$1.00 per hour for a profit-making, turn-keyed system leased to a school system, including software and commercial cost of loans and capital.

### The Courseware

- The equivalent of five full semester courses will be developed in English and in math.
- Learner control over the instructional strategy is a basic tenet of the University of Texas' instructional design philosophy, as a means to humanize education and minimize the inadequacies of machinery.
- The University of Texas' and Brigham Young University's instructional design concepts replace courses of conventional instruction with completely modular systems, greatly redefining the teacher's role. Dramatic increases in effectiveness are sought through the use of a systematic design approach.

### The Market

- The TICCIT curriculum should have a major, measurable, and nationally meaningful impact on two junior college student bodies.
- A new junior college is being formed in the United States every two weeks, on average, and approximately 50 percent of first-time enrollees in U.S. public collegiate institutions in 1969 were in public junior colleges.

- Almost 20 percent of all junior college class contact hours are in curricular areas chosen for this program.

Elsewhere in the proposal, we learn that The MITRE Corporation had invested \$750,000 of its internal R&D funds in this program before the NSF funding was obtained. In addition, the proposals detailed extensive plans for coordinating with manufacturers, publishers, school administrators, and others to assure that the project would recruit additional investment and interest of businesses and customers alike in actually achieving the "Market Success" after the NSF funding period was complete. The two community colleges selected, Northern Virginia Community College near MITRE and Phoenix College in Arizona, were the sites where the evaluation occurred, and where many lessons were learning in subsequent years.

MITRE Corporation had been developing a number of technological innovations in TICCIT in hardware and software for digital audio and graphics. MITRE started with the name TICCET (Time Shared Interactive Computer-Controlled Educational Television) and very soon thereafter changed it to TICCIT. They changed "Educational Television" to "Information Television," thus

broadening the scope of application of the technology to include home-based information interactions over cable. Their solution, integrating as it did video, color slide projection, and print, was quite advanced for its time. Now, happily (even miraculously, for many writers in this book who pushed the envelope of the ancestors of today's technologies at great human and financial cost), the cost concerns dealt with in this proposal for hardware and software have been revolutionized by progress in the information technology industry. The several racks of cards and wiring for digital audio, graphics, and the videotape players used in the TICCIT system have been replaced by a few chips, with a DVD drive if you wish.

The original hardware featured two NOVA 800 minicomputers, a terminal processor, and a main processor. The terminal processor was designed to handle communications with 128 Sony color TV sets adapted as terminals. TICCIT systems were rolled out over a couple of decades following the end of NSF funding by a series of corporations, first by Hazletine, then Ford Aerospace, then Loral. It had a relatively long life, more in military and industrial applications than in its intended target, schools.

The courseware team was consolidated at BYU in 1972 as a result

of the following considerations. Based on the work of UT doctoral student Dan McLallen (1971) MITRE and the UT lab jointly choose community colleges as the implementation site and the subjects of freshman English and freshman mathematics as the target courseware projects. McLallen's dissertation showed a high penetration of credit hours that these two subjects would encompass out of the total of most community colleges. The penetration would be much greater, and the project would be challenged with more remedial students by extending both the math and English courses downward to encompass more building-block lessons from high-school and remedial levels. When the amount of courseware to be developed was dramatically increased, Brigham Young University (BYU) was selected to develop these additional lessons.

As head of the courseware development and authoring system team, I evaluated the resources needed to pull off such a large courseware development project and found that my resources at Texas would be taxed. I looked to a respected colleague, Dr. M. David Merrill, with whom I had developed a strong working relationship during his time at the George Peabody School at Nashville. One of my doctoral students at UT Austin, Paul Merrill, was studying a

computerized version of Dave Merrill's hierarchical "imaginary science" lessons for his dissertation at the time. When Dave Merrill moved from Peabody to BYU, he was alive with excitement about the unusual and coordinated resources at BYU for the design and development of innovative learning technologies. Darrell Monson had risen to a high administrative position at that campus and had under his direction an outstanding movie studio, learning labs, and radio and TV station. With Merrill, Monson was using his influence in setting up a graduate program in technology in education—we later named it Instructional Science. I felt that the opportunity to apply these resources to the TICCIT project through a team united in one location would greatly enhance its likelihood of success.

Instead of subcontracting the remedial portions to Merrill's team under Darrell Monson at BYU, with counsel from MITRE and NSF, and with understanding support from Wayne Holtzman at Texas (who was the real founder of the Texas Lab and my mentor), I decided to move the project to BYU. Up to that time, only a planning grant had been given to the UT CAI Lab. This move was of great importance, as Dave Merrill and his colleagues at BYU had an enormous

impact on the design and features of TICCIT. Merrill's component display theory of instruction was at the heart of the interaction design, and he practically single-handedly worked out the details of the advisor program we had determined was essential in a learner-controlled system with navigational maps. Combining forces helped reduce costs substantially for travel and for duplicate equipment. Also, it reduced maintenance and management problems of a split team (it was hard enough to manage it at one location!). These were some of the reasons the consolidation was favored by MITRE and NSF. I brought key graduate students and courseware experts from UT, including colleagues Dr. Gerald Faust and C.J. Ross, math professor Dr. Ted Boessenroth, systems programmer Steve Fine and his able wife Claire, Tom McMurchey, and graduate student Fred O'Neal and his capable wife Harriet. Like Claire, Harriet became a manager within the Courseware Production Factory. Dave Merrill's team included Drs. Harvey Black, Ed Green, talented graduate students, including Andy Gibbons and Roland Blake, and many others. These and other people who joined the team later comprised the Courseware team, which was consolidated at BYU in the summer of 1972. Those joining the

team after the initial consolidation are not listed, but their contributions are not forgotten.

This team worked out the details of learner-controlled courseware. Steve Fine and Tom McMurchey provided the main technical interface with the MITRE Corp engineers. With other members of the courseware team, they later joined Hazletine to see the TICCIT system through its generations, which included the migration of TICCIT to PC's—MICRO TICCIT.

In reference to such market successes the TICCIT system did attain, and the many spin-off companies influenced by TICCIT alumni, it can be argued that team production of componentized, model-based courseware built on the separation of content from logic has perhaps led to more "market successes" in online interactive learning projects and in many companies than any particular system on which it was embodied. Faust, Merrill, Ross, and Bunderson and others started Courseware Inc. Dr. Dustin Heuston and Bunderson co-founded WICAT Systems and the Waterford school, and recruited many members of the TICCIT team. Heuston and WICAT's president, Bob Mendenhall, later agreed to merge WICAT and PLATO into the PLATO-

WICAT company. This company later split due to business reasons, but showed that business is happy to use the best of either system. Another instance of this: Bunderson served for a time as vice president of research and psychometrics for TRO Learning, the company that bought PLATO. Heuston's Waterford school and Institute is today a strong contributor to computers in early education. Bunderson also founded what today is called Alpine Testing Solutions and The EduMetrics Institute. Dave Merrill was instrumental in several start-up companies, and his consulting to large training companies, such as NETg, has taken ideas developed during TICCIT times out in many directions. Other TICCIT alumni have been involved in many e-learning ventures. Of particular note is Dr. Robert Mendenhall's career. He started as an undergraduate pre-law student who helped Bunderson manage the TICCIT lab during and after the evaluation period. He gave up law school to become general manager, then president of WICAT, became head of computer education at IBM, got a Ph.D. from the BYU department of Instructional Science, and is today the president of Western Governor's University, a fairly recent "market success" as the nation's first fully competency-based university. As

discussed below, it embodies several of the most important lessons from what was right and what fell short with the early TICCIT.

Since hardware and software technology change so rapidly, the disciplines of design-science-based development and team production and the architectural features pioneered in TICCIT have provided some stability to enable predictable and productive courseware production. Courseware, after all, is where learning may occur. Many concepts and people from TICCIT have indeed had a broad influence in the market for what CAI has become.

“Learner Controlled Courseware” was the byline of TICCIT. It was meant to suggest that instructional materials—Courseware—could be developed by a principled process that assured a high likelihood of instructional success, and that the elements of that courseware—instructional variables—could be placed in the hands of the learners through a “learner control language” implemented through a special keyboard. The TICCIT courseware team tried to convey with these words that the expertise learners could gain through becoming proficient with the learner control language would accelerate their progress, not just through the TICCIT math and English

lessons, but also their attitudes of responsibility toward learning and their eagerness and confidence in taking on new learning opportunities.

### **The Evaluation of TICCIT's First Year in the Colleges**

NSF provided an additional \$1 million so that researchers at Harvard University and

the Educational Testing Service could evaluate both TICCIT and Plato. This they did with skill and depth, visiting both before the implementation and later collecting outcome data for a year in the two colleges. Patrick Suppes provided a succinct summary of the evaluation of TICCIT in an important article on the state-of-the-art of CAI in 1979. Suppes was the main consultant called on by Eric McWilliams, the very effective NSF program manager in site visits to evaluate the progress of the BYU and MITRE team. Suppes kept our feet to what he regarded as the appropriate fire. He did this by drilling into one topic during each visit; nailing us to the wall on the issue during the visit. After the NSF visitors left, we got down off the wall and tried to correct our sins of omission or commission. While his summary is terse, it is backed by his extensive personal

knowledge of the TICCIT project (Suppes, 1979, p. 189).

"The TICCIT project had the responsibility to develop two community-college courses, one in English and one in mathematics. The curriculums of the two courses are fairly standard and will not be reviewed here. The more distinctive feature of the TICCIT courses has been the effort to use an explicit instructional strategy focused on learner-controlled courseware (Bunderson, 1975; Bunderson & Faust, 1976). The Educational Testing Service (ETS) evaluation of the TICCIT courses, as summarized quite objectively in Bunderson (1977), presents the following conclusions (see also Alderman, 1978).

"(1) When used as an adjunct to the classroom, TICCIT (like PLATO) did not produce reliable, significant differences in comparison with classes that did/not use TICCIT (or PLATO).

"(2) When used as an integral scheduled part of either mathematics or English classes, TICCIT students did significantly better than non-TICCIT students.

"(3) Characteristics of the teacher are significant in determining the performance and the attitude of students in both TICCIT and non-TICCIT classes, a conclusion that matches much other research of a similar sort.

"(4) There was a difference of about 20 percent in completion rate in favor of non-CAI classes for the TICCIT classes.

"(5) The success rate of students who took the TICCIT mathematics more than once seemed to indicate that the courseware did not provide sufficient remedial depth to teach some of these students.

"These results are not terribly surprising. It seems to me important that we do not have some immediate evaluation of CAI on the basis of a single year's test as in TICCIT or PLATO. It is rather as if we had had a similar test of automobiles in 1905 and concluded that, given the condition of roads in the United States, the only thing to do was to stay with horses and forget about the potential of the internal combustion engine."

Suppes ends his review of the ETS evaluation appropriately in cautioning against jumping to premature conclusions. Ending an evaluation after one year is indeed a poor evaluation strategy. It was expensive enough for NSF, but I now recommend that evaluation strategies should take on a design experiment flavor by spreading costs over more cycles of evaluation and revision.

### Focus of This Article

Many stories can be told of these times, stories generated by the hard

and soft technologies, the instructional psychology and research adventures, the sobering realities of

implementation in organizations, for example, the irony that educators who were often thrilled with the words about learner control and learner initiative but had a need to stamp it out when it actually started to occur. Some of the most interesting stories involve the people who passed through the labs at UT Austin, BYU, Courseware Inc., WICAT, Institute for Computer Uses in Education, and other companies that built on TICCIT concepts. Except for the few side comments, however, in this short article I will be content to tell just three stories about lessons that have endured; about important problems that remain unsolved. These three stories are about:

1. *Learner Control*. How far did we actually go toward understanding and realizing the depth of what lies beneath this term?
2. *Progress Maps Culminating in Mastery Assessments*. How well did we understand the importance and the science at the base of these artifacts?
3. *Differentiated Roles and Technology Integration*. We boldly proclaimed in the proposal that the teacher would not be replaced, but that teachers' roles would be greatly differentiated. How little did we really understand that

statement, and what did we learn—during TICCIT and afterward?

Stories not included here:

Instructional Theory, Component Display Theory, and Concept Elaboration Theory, which was born during the TICCIT project at BYU. Instructional theory stories are best told through the writings of M. David Merrill, Charles Reigeluth, and others. Other information on TICCIT and its features can be found in the excellent book prepared by Dave Merrill, Ed Schneider, and Kathy Fletcher (Merrill, Schneider, & Fletcher, 1980). This book provides details of the TICCIT learner control strategy, the testing strategy, the materials development methods, and many other details not found in this article.

### **Learner Control**

Before TICCIT, the UT CAI lab team conducted learner-control research by giving

the learners more and more control within the hierarchical structures of prerequisites used at that time to model the domain. Also, the learner controls were constrained by the type of tactical options we had then imagined that learners would need (see Judd, Bunderson, & Bessent,

1970). This research was equivocal on comparing the effects of learner versus program control on criteria of efficiency and effectiveness. Although the UT team built larger-than-usual systems,, it was doubtful that the scope of the online learning experience was extended enough in engagement time to determine to what extent the ability to control one's own learning may be a skill learned slowly and requiring substantial practice.

Looking back from today's perspective, it is easy enough to ask: Why not? Proficient reading itself, library searching, and now Google searching is a skill that manifests very wide differences in individual proficiency. In 1971, we had begun to suspect that learner control might take a long time to develop, but we wanted to believe that the TICCIT courseware experience would be extended enough to show an effect. At least, we thought, questions about learner control had a better chance of permitting proficiency to be developed during the TICCIT courses than in earlier supplementary lesson systems.

When proficiency in directing one's own learning is seen as a domain itself, perhaps this "learning to learn" proficiency is as valuable as or more valuable than the outcomes in mathematics or English TICCIT was designed to teach. If this is so, then

the nature of the "controls" interaction designers give to the learner are vital. But unless the learner controls act within a system that itself is modular and model-based, how can a learner come to grasp the meaning of the controls? Imagine a pilot in a cockpit. A good pilot has learned to understand immediately the meaning of multiple dials and gauges and instinctively to move the steering wheel or joystick, often reaching simultaneously with the other hand for other controls. Based on an interpretation of information seen through the window and from the displays reporting measurements, the pilot can take just the right action required to further a mission in the face of the unexpected. The information displays present information that permits a knowledgeable pilot to infer actual states of what key abstract constructs refer to. These constructs include altitude, speed, wind direction, and geolocation.

These readings interpreted by the pilot all have a theory behind them and have physical consequences that will follow lawfully and often very quickly. They are not ad-hoc points of decision in a learning content space that has no coherent structure or theory behind it. What information and controls should be given while learners are engaged in a mission

in a learning space? By analogy, information should be presented that ties into a coherent set of abstract constructs related to progress and location in a learning domain. This interpretive framework will reveal a model of the domain. It will certainly contain learning milestones and goals and status information, such as TICCIT provided with the Objectives and Status display. This TICCIT map provided access to objectives describing what goals were to be attained and colored status information depicting progress. Based on possible interpretations of this information, the controls the learner needs should offer great utility in enabling the learner to reach those goals safely and expeditiously, from wherever a learner may be within the domain at a given time—and despite whatever difficulties that learner may have encountered in getting there.

The nature of the domain of proficiency in learner control is certainly central in understanding learner control. Another issue became the focus of considerable attention before and during the TICCIT project. It was this: What other characteristics besides (cognitive and psychomotor) proficiency might develop through the use of learner control of instructional variables? We are dealing here primarily with variables having strong

non-cognitive components: volition, motivation, persistence, and voluntary approach versus avoidance. Other terms are conation, affect, attitudes, and dispositions. Quoting again from the 1971 proposal to capture the words and ideas of that time (MITRE, 1971, p. 73):

“In summary, minimum evaluation of the success of this project is dependent only on criteria of cost, efficiency, and effectiveness relative to baseline data in junior college math and English. . . . However, the courseware design is styled and structured in fundamental ways to conform to values and suppositions about the future which be beyond stated performance objectives. . . . The goal is to encourage self-motivated, skillful independent learning which will lead to further self-initiated encounters with the subject matter by as many students as can be induced to accept the challenge.”

How well did we do in achieving the non-cognitive goals? The ETS evaluators discussed them as background ideals (Alderman, 1978, p. 29):

“Goals, after all, tend always to exceed our grasp. . . . Since goals influence decisions, it seems reasonable that such statements balance an enthusiastic optimism about potential accomplishments and an historical realism about results of prior

work. Here we took the developer's goals as earnest statements of intent which should guide, though not dictate, our attention in evaluating the TICCIT program."

Thankfully, the ETS evaluators did not seriously try to evaluate our attainment of these goals during that first year of learning how the two colleges were going to cope with what we had produced. Many adjustments had to be made to get the best results out of TICCIT. Now the usual term is "Technology Integration."

We went into the implementation thinking that the planning was adequate. The systems engineers at MITRE put capable Ned Burr on the job, and he worked with us to produce a massive document called an "Implementation Plan." It seemed to cover everything, training, documentation, dealing with people's attitudes. We academics were very impressed with this evidence of MITRE's experience in implementing large-scale projects, but we learned how little we had really understood. Students unfamiliar with TICCIT CAI—with any CAI at that time—would first have to learn how to take action to work on the system and complete their lessons, let alone change their proficiencies to learn, and their attitudes and dispositions. Teachers would have to learn what to

do to help the students attain these simple fundamentals.

Still, there was enough positive evidence to cheer us, even in that difficult first year that the evaluation targeted. Some of the students really loved it. Some of the students succeeded where likely they otherwise wouldn't have. On average, once they had completed TICCIT, their scores were higher than those in the lecture groups.

In the TICCIT design experiment described below in connection with the third TICCIT story, and as implemented in the differentiated staffing model of Western Governor's University, we have found approaches that will work well for technology integration. "Technology Transfer" is not an adequate term. It is not enough to transfer tools to a group organized in a conventional manner, following established roles and rules. The biggest role shift is in the students' role. It is necessary to reorganize roles and rules substantially and to teach the students new ways of organizing their time and methods of learning. These new patterns of learning include both individual work and learning to work with cohorts of students with similar goals. These changes result not in technology transferred into an existing system, but in what really should

be described as a new system. Since conventionally organized educational institutions find it difficult or impossible to implement such radical changes in the roles and rules around which they have been organized for decades, even for centuries, the technology is too disruptive to use in the ways that might work best.

Disruptive Technologies: Clayton Christensen uses the term “disruptive technology” in his book *Innovator’s Dilemma*. He explains how a technology that the current system has difficulty using can become a market success: He points out that the way a disruptive technology might finally achieve a market success is to skirt the existing customer base and go to market niches underserved by the existing technologies. In education, organizations like University of Phoenix, Western Governor’s University, and other online universities have found such a niche—thirty to forty some people with family and work responsibilities who cannot travel to campuses and take classes scheduled during their prime work time. As these organizations achieve market successes in a new niche that does not require the same definitions of roles and rules of procedures as the campuses, a point is reached when the offerings of the disruptive technology vendors become so well understood

and improved through riding up the learning curve of technology that they begin to compete with the established markets.

Back to the Learner Control Story: Evaluating CAI, including TICCIT as a disruptive technology does not take TICCIT’s learner control strategy off the hook. It is clear that the controls provided and the information displayed on the maps was not sufficient to achieve the broader vision of what learner control is all about. For one thing, it did not span an adequate range of preferences as shown in different models of thinking and learning preferences. My colleagues and I have conducted extensive validation research with the Herrmann whole brain model of thinking preferences using large international databases of surveys taken over the last twenty-five years (Herrmann, 1988—see validation appendix; Bunderson, Wiley, & McBride, 2007; Olsen 2007). This model interprets four clusters of preference choices, made under scarcity. By scarcity, we mean that the respondent has limits on how much can be chosen in expressing preferences. The preference clusters form at opposing ends of two bipolar factors. One bipolar factor favors analytical, logical, mathematical thinking at one end and interpersonal, emotional, thinking favoring an

interest in human relationships at the other. Experience has shown that these preference clusters are relevant to what type of learning environment and instruction work best for an individual.

TICCIT designers provided a lot for those who favored the logical left brain. There were plenty of displays involving logic and algorithms, found in the rules and helps.

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*TICCIT designers provided a lot for those who favored the logical left brain.*

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Unfortunately, what many people-oriented students needed was to work in smaller or larger groups with others. They could work around open tables on their own TICCIT terminals, but did not prefer the walled-off carrels in the TICCIT lab. They preferred more human interaction, and we eventually learned how to provide it.

The other bipolar factor in the Herrmann model features preferences for order, organization, and step-by-step methods at one end and creative synthesis, taking risks, seeing the big picture at the other. TICCIT was very organized and orderly, with a place for everything and everything in its place. What some of the students needed was to see the big picture more completely than the TICCIT map hierarchies conveyed. They needed better options to explore and try out

synthesizing tasks at a high level of generality. They needed practice going beyond fixed lists of items into larger, more synthesizing projects, perhaps even leading to capstone projects that tie lower subdomains and objectives together.

The TICCIT English project had its writing assignments, and our greatest documented successes with TICCIT came through freeing the teacher's time up by letting TICCIT teach the grammar, mechanics, and organization lessons. This enabled the teacher to spend more time managing and mentoring writing assignments. Otherwise, the TICCIT learner control strategy was all within the organized, step-by-step type of thinking favored by only one of the four quadrants of thinking preference.

Can we really hope for dispositional changes in students when they are given more choice of controls that really matter and plenty of time to practice it? The jury is out on some of the goals we had, such as enhancing a voluntary, eager approach to learning. The doctoral work of Margaret Martinez (1998) poses a challenge to the supposition that dispositions are really very modifiable. She has identified four "learning orientations," the transforming, performing, conforming, and resisting learner. These "orientations" may

shift through learning, but apparently only with great difficulty. Martinez teaches instead how to maximize the effectiveness of learning using the orientation you have already established.

Whether one's orientation is due to genetic nature or nurture and life experiences, a transforming learner is going to want to see the big picture and jump around a lot, if given the learner controls. The conforming learner wants to be told just what to do, and what steps to follow to do it. The resistant learner is not going to buy in at all, but when s/he does, look out, this may be a transforming learner in disguise, one who can come to love learning. A person in resistant orientation may be one who has refused to buy into seemingly stupid demands and assignments administered in a structured educational system they hate. Some kinds of learner control may work to effect a leap of members of this group from resistant to transforming learning.

In most environments, the orientation forming the biggest group of learners is called "performing learners." They know how to learn and will tolerate the system, but their goal is to minimize effort in checking off the attainments the system demands. They have attitudes that could lead to

the behavior noted above—TICCIT students who over-used the advisor to find out just how many more problems they had to work in order to pass out of that lesson.

**Does Learner Control by Any Name Have a Future?**

Going way beyond the highly structured TICCIT approach to learner control,

do instructional psychologists/technologists today see anything in the rapidly changing world of technology—any evidence of the eager motivation that impels the learning of any content, logic, or skill required? Perhaps. We see the young give big parts of their lives to becoming amazingly proficient in role-playing games. We see incredible Massively Multiplayer Online Role-Playing Games (MMORPG) like World of Warcraft that require the development of superior social and leadership skills to organize people and material for successful campaigns of conquest and acquisition. As John Seeley Brown (Brown & Thomas, 2006) has pointed out, the skills attained by a seventh level Guild Master are the skills needed to organize people and accomplish complex and important missions in corporate global business.

The motivations are there in games. These are the powerful motivations

the TICCIT designers dreamed of for learning environments, but could not attain through structured lessons focused directly at learning objectives. The funny thing is, the goal of a game is not learning. Learning is an incidental by-product of deep investment in the goals of some imaginary game-world. These are larger goals that matter to the people who choose to make the investment. Education has broken the subject matter into neat little packages that build on one another to permit a class credit that enables one to take another class, then another, until one earns a degree.

The role restructuring for the individual learner is there in a game world. In an MMORPG, what the learners control is a comprehensive set of functions. They choose from and also shape available goals. They control the methods for obtaining the means needed to seek the goals.

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*Gamers have multiple measures of progress at hand.*

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They learn skills and strategies for fighting to keep and add to the means toward the goals they value, and so on. Gamers have multiple measures of progress at hand—their level of character attainment in each of their avatars, their wealth, health, strength, possession of weapons, possession of defenses, and on and on.

It is a broad synthesis of navigational utility made subject to the gamer's growing intelligence by a growing knowledge of what the different measures of attainment mean. Games might connect in a sort of oblique way with academic curricula in schools and colleges, but that connection is hidden and incomplete at best.

Perhaps most important, life in an MMORPG is life in a meritocracy. True, you can buy your way to more rapid advancement with enough money, but you still have to perform to stay there, and continue to perform to attain more. Thus complex multiplayer games are meritocracies. Schools and many other human institutions are hardly meritocracies.

In searching for the motivational power to attain high levels of proficiency and to gain strong dispositions toward continued learning, the designers of TICCIT made some very small steps toward the non-cognitive goals, and toward the idea of high levels of learning proficiency. I am impressed with the online meritocracies in the open-source world of the Internet and in the game worlds. An increasing number of online communities are structured as meritocracies, such as *Slash Dot*, wikis, and user communities associated with online tools, (especially open source tools). These

communities are structured around pure technology expertise at present, even though more effective and faster transfer of expertise might occur with the application of learning design and measurement disciplines.

It is easy to lament their lack of recognition of instruction, measurement, and the like in the new meritocracies of digital expertise. It is easy to lament that a little technology expertise often trumps experience and know-how in instructional technology. But let it grow. Maybe instructional technologists can learn as much or more from the digital natives as they could (but probably won't) learn from the instructional technologists. Is this where the broader mission of learner-controlled courseware is going to find some fulfillment?

**Progress Maps  
Culminating  
in Mastery  
Assessments**

Progress maps display learning progress and goal information and provide

navigational controls.

The TICCIT map (objectives and status display, with navigational control) is a concept that has far more depth than we realized at the time. While the RULE EXAMPLE PRACTICE EASY HARD HELP tactical commands have not sustained a large amount of continued research

and attention, the broadened concepts behind TICCIT maps are likely to receive increased attention.

After working at WICAT for a time, I had the opportunity to work at Educational Testing Service as vice president of research management during a period of intensive work on the goal of developing new applications of testing integrated with learning. One ETS initiative in the research division during those days was to develop examples of "Learning Progress Systems." Such a system was conceived of as having a map or interpretive framework for valid measurements of progress along meaningful pathways of learning progress. The concept was seen as one of several possible ways to implement Systems which Integrate Learning and Instruction (SILAS; see Snow & Mandinach, 1999). ETS continues research with this intention under a variety of names and descriptions.

I brought to TICCIT a background in measurement from Princeton and from a practical and theoretical education at ETS as a Psychometric Fellow. I tried to assure that the measurement systems underlying the TICCIT practice files, status displays, and advisor status information were respectable. Dr. Edward Schneider joined the TICCIT team at BYU and developed an adaptive testing system

for the TICCIT tests, based on the Wald sequential testing approach (explained in Merrill-1980). Students did not need to take all the test items in the file. They could pass out or fail out more quickly.

The interpretive framework feature of a learning progress map, discussed as crucial to learner control in the last section, depends on having a theory by which the measures of progress can be judged. In TICCIT, we had produced a Gagne-style "learning hierarchy" for each lesson and unit, and indeed, for the entire course. The rules for producing these hierarchies were based on analysis into the classes of learning described by Gagne in his 1985 book, *The Conditions of Learning*. These categories were modified somewhat to fit Merrill's Component Display Theory. Such a learning hierarchy produces one type of theory of the domain, but I left the TICCIT experience thinking that this type of learning hierarchy could result in fragmented instructional pathways. The TICCIT rule-example-practice strategy worked well with concepts and simple rules and procedures, three of the Gagne/Merrill types of learning, but not so well with performances that were integrated at a higher level. We had noted this problem of fragmentation versus integration and had developed the concept of a "work

model" that integrated performances at a higher level (Bunderson, Gibbons, Olsen, & Kearsley, 1981; Gibbons, Bunderson, Olsen, & Robertson, 1995; and Gibbons & Fairweather, 1999, Chapter 15).

Charles Reigeluth struggled with the problem of fragmentation versus integration as a graduate student at BYU during TICCIT times. Later, he has written on Concept Elaboration Theory (Reigeluth, 1999) in an attempt to deal with unfolding sequences of increasing complexity, rather than fragmented learning hierarchies.

Returning to an academic environment at BYU in 1991, I worked with several colleagues and graduate students in an effort to understand the measurement foundations for progress maps and how to develop them. Influenced by the work of Samuel Messick on validity, we developed concepts of a "Domain Theory of Progressive Attainments" (Bunderson, 2006, Bunderson, Wiley, & McBride, 2007). A domain-specific theory of progressive attainments is one candidate of replacing the learning hierarchies used in producing the TICCIT maps. The definition of validity presented by Messick (1995), by the writers of the Joint Standards on Educational Tests (AERA, 1999), and by other validity theorists is the key to understanding the need for an

interpretive framework in a domain. Validity resides in interpretations and actions taken in response to an understanding of what measurements mean; validity does not reside in a measurement instrument itself, or in its scores. Therefore, if the users cannot interpret the meanings of measures, they cannot respond quickly and adroitly through controls whose use depends on a correct interpretation of the measures. Validity is lacking in such a system, and the broader goals of learner control discussed in the last section are unlikely to be achieved.

As this work progressed, we discovered other work in a similar area that also represents a basically compatible and very promising approach to the development of progress maps. This work by a number of investigators has been done under the heading Knowledge Spaces (see Falmagne, 1990, for an early account). A *knowledge space* is itself a rigorously defined domain-specific theory of progressive attainments. It has a promising mathematical foundation. *Knowledge spaces* is a candidate for the theory of the domain structure needed as a foundation for developing the type of learning progress maps envisioned here.

The emphasis in our work has been on assuring that learners can interpret and use the information the

map provides, which is the essential meaning of modern conceptions of validity.

The idea of navigational control throughout a courseware domain and the idea of meeting the conditions of conjoint additive measurement in the measures reported on that map to guide learning progress are still under development at the EduMetrics Institute; also, it is found in the work of a number of young Ph.D.s who did their dissertations on aspects of a domain-specific theory of progressive attainments in areas of interest to them (Bunderson, Wiley, & McBride, 2007; McBride, 2005; Strong-Krause, 2001; Xin, 2002).

One of these former doctoral students is Dr. Thomas Zane, director of assessment in the NCATE-accredited Teachers College of Western Governor's University. As mentioned above, WGU has been able to implement a role-differentiation approach that separates the roles of teaching, assessment development and administration, mentoring, tutoring, grading, and other matters. The WGU approach includes social and organizational variables that help solve the problem of low completion rates manifested so sharply in the ETS evaluation of TICCIT. Fundamentally, WGU shifts the student's role and separate a variety of teacher roles.

WGU is a competency-based university with a method for defining credible domains and developing aligned assessments. WGU starts the process of domain definitions in a conventional manner, defining domains, subdomains, competencies, and objectives. Developing a full domain theory of progressive attainments in a domain would require integration beyond the use of objective and competency statements into pathways that reflect integration at higher and higher levels of complexity. Feasible steps toward this ideal are taken by Tom Zane, whose team is encouraged by the University officers to use integrative performance measures, not just objective tests. Zane uses concepts like work models, cited earlier, and for assessment, makes heavy use of performance tasks, domain level projects, and capstone projects that integrate across domains. Zane's staff uses these methods in developing, evaluating, and improving new WGU assessments. This assessment group is able to take appropriate steps, sometimes small ones, sometimes larger, that fit the state of development of the student population and the state of development of WGU. These are steps toward realizing a fuller vision of measurement of learning progress

based on domain-specific theories of progressive attainments.

**Differentiated  
Roles and  
Technology  
Integration**

This last story describes how design experiments using differentiated

staffing models as a replacement for premature evaluations can lead to the attainment of more of the hoped-for high expectations for TICCIT.

The news of low completion rates from the junior colleges hit us hard at the TICCIT lab at BYU. Now reduced to a fraction of the staff we had during the TICCIT courseware development effort, we were still burning to know how to make the exciting TICCIT concepts work in practice. It was clear that students didn't already know how to use a system like TICCIT to learn on their own, and that only a relatively small percentage of students really had the characteristics Maggie Martinez later identified as those of a "Transforming Learner." These are the learners who can learn on their own in almost any environment. We believed that the innovative TICCIT system was really still in its toddler-hood and that its users needed to learn many things to help it grow up.

To do this, we found that faculty support at BYU was not strong.

English faculty at BYU were polite but disinterested. Math faculty would not use TICCIT in the appropriate classes. TICCIT, after all, dealt with low-level community college material and did not honor math faculty members' vision of the importance of their unified and dominant role. Most English faculty members were interested in teaching literature, and this left graduate students free to teach writing with a fair amount of freedom. The English faculty allowed the TICCIT lab to recruit several graduate students who were teaching sections of English in preparation for the university-wide required writing exam.

All sections at BYU took the same test at the end of each semester. The test consisted of two parts; a multiple-choice grammar and mechanics test and a written essay graded by teachers according to generally accepted standards. It is unusual for a university to develop one standard measurement system for all sections in a particular domain, but this was one of those unusual times. The tests were scored by classical means and lacked desirable invariance properties, but were suitably comparable for the large effects noted. A design experiment takes place over repeating cycles of implement/evaluate followed by redesign, revise the social and

organizational conditions. Comparison from cycle to cycle depends on the comparability of the measurement—their invariance properties—from one cycle to another. The cycle for these college English classes was one semester in length.

During the first semester, several graduate student instructors taught TICCIT sections. We will examine the results of two of these student instructors. The first one (Christine Hansen, who with advanced degrees later became head of all the BYU writing labs) tried hard to integrate the computer. TICCIT had a set of tutorial lessons in grammar and mechanics. It also had writing lessons dealing with audience, purpose, structure, and outlining. The second teacher did not believe in the computer, but was confident that she could teach students to write. The baseline and the results of the first cycle of the design experiment are illustrated in Figure 1. This figure uses the term

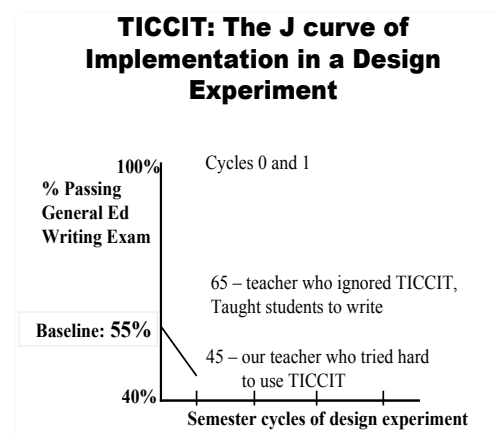


Figure 1. Results After One Cycle of TICCIT Design Experiment

"J-curve of implementation," borrowed from economics. The curve of percent passing drops before starting up again.

"Cycle 0" was merely to obtain baseline data from all the conventionally taught English sections, so future cycles of design and improvement could refer back to it. The results of Cycle 1 were not promising for the teacher who sincerely tried to use TICCIT as it was supposed it should be used. On average only 45 percent of her students passed the GE exam. The other teacher said to her students in a variety of ways: "Go use that computer we're supposed to use in whatever way you wish, but here in my class I'll teach you how to write." The result of her efforts: 65 percent of her students passed the GE exam. The baseline average was 55 percent across the university. After one cycle, the logical conclusion would be to teach the methods of the second teacher to teachers in the other sections, and not use TICCIT at all.

But the English faculty had delegated Freshman English to graduate students, and we were spared the risk of pre-judgment or premature judgment.

Christine Hansen believed she could organize and get much better results during the second cycle. The team of researchers studied data available on

the classes taught by all teachers in the study. TICCIT generated extensive data on student progress in every lesson and every segment of every lesson. From observation and data, It was easy to see that students had no habit patterns for how to learn on their own with a computer. As was found with the community colleges, the computer was greatly underused in the BYU lab, although the BYU college students appeared to have greater success in lesson completion than had the community college students. The committed teacher and her support group designed better implementation plans for the second semester, plans designed to help the students understand their roles better, and the teacher to redefine her role and her new rules of procedure. No changes were made in the hardware or courseware, just in the implementation of new roles and new rules. Students were organized into small groups and scheduled to meet at computer terminal tables, where they could see and talk to one another. A "party" was held in the computer lab to get them started and to assign tables and small groups of cohorts. At the end of the second cycle, the TICCIT teacher's class did better than the second teacher's had the previous semester, 72 percent compared to 65 percent, and substantially higher than baseline.



Figure 2: TICCIT Individual Carrel (Above) and Open Group of Table-Mounted Terminals (Left)

More TICCIT lessons were completed in Cycle 2 than in Cycle 1.

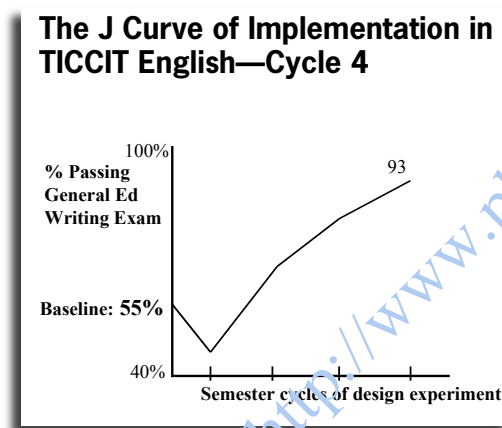
Figure 2 illustrates one of the environmental adaptations used to create a social environment among the TICCIT English students. The upper picture features a very private, one-student TICCIT carrel. Designed with human factors expertise by Dr. Edward W. Schneider, this carrel featured no glare on the screen, a stand for books, spaces on each side—privacy for only one person. The bottom photo shows a long table with no partition, designed by Schneider as well. With TICCIT terminals on each side, this arrangement enabled students at the table to see their friends and talk over the table and to those seated at each side. Their regular seats and their group of six was set up at the

beginning of the semester, and they came to the TICCIT lab at the same time, as though it were a regular class period. Each group had a name, such as “Emerson” or “Thoreau.”

Hansen, backed by the TICCIT team, still believed she could do better. This team also believed that the students, backed by professional developers and researchers, could do much better, so more changes in roles and rules were made. At the end of the third cycle 84 percent of that semester’s group of students in the TICCIT section passed the GE exam. The students in these subsequent semesters accepted their role to learn and practice grammar, mechanics, audience, and purpose on the computer, and the teacher spent more time with small groups motivating and mentoring them in

how to write. The team made further refinements and tried again. At the end of the fourth semester, 93 percent of this new group of TICCIT students passed the two-part GE exam. Significantly more TICCIT lessons were being passed, and the scores on the objective grammar and mechanics test were significantly higher. Even higher was the improvement in writing scores—this was the key to the strong performance of the TICCIT-using teacher's students on the writing exam. See Figure 3 (Below).

Figure 3. TICCIT Design Experiment Results Over Four Semesters



The improvement in Cycle 4 has an effect size of .96 from baseline, and even higher from the low-point in the J curve. This high pass rate for Cycle 4 was attributed to the teacher beginning to use the reports generated by the computer system to identify the number of TICCIT lessons the students were completing. This implementation tactic was added to further refinements in the previous successful implementation methods

for working with small groups. Using the reports, those not making good progress could be identified early and encouraged and taught individually, while most of the class was involved in practicing and studying on the computer or working on their writing.

This large effect was attributable to variables entirely from the social and organizational realm of implementation or change management. There were no NSF or University funds left at that time to redesign the hardware, software, or courseware. Bob Mendenhall was an undergraduate research assistant during these TICCIT studies.

He went on to become general manager, then president of WICAT Systems. This company recruited a good number of the TICCIT team members. As president of Western Governor's University, he now uses as a standard management strategy the best measures he can get for all aspects of the University's functioning, and insists on making revisions and following up to see whether the measures improve in the desired direction. It is not as tight as a design experiment, but does not require publication of results, and it is cost-effective for an organization. The WGU model of differentiated staffing is one viable model for e-learning in higher education. The

model is documented at one stage of its development Mendenhall's (2001) dissertation, but due to continuing data-based revisions since that time, the differentiated staffing model and other aspects of the WGU model have shifted a bit since that time.

### Conclusions

Projects and systems come and go. People move on to other challenges

and other accomplishments. As in every field of human endeavor, some problems in succeeding with CAI are very difficult to solve. Three stories were told about TICCIT and about continued efforts to solve a class of problem. In the Learner Control story, a key problem is capturing enough motivation in an e-learning system to attain the broad goals of increased, transferable proficiency in learning, strong and eager approach toward further engagement with the subject, and a strong sense of personal responsibility for learning progress and learning attainments. It is not clear that some of the non-cognitive traits associated with successful learning are teachable and learnable, even with an ideal learning language, progress mapping interface, and given long engagements in systems that use them. It may be that some preferences

or orientations toward learning will prove difficult or even impossible to change. It may be better to find strategies to help learners become more successful within the constraints of different preference profiles, learning orientations, or dispositions.

Looking ahead, systems radically different from TICCIT's highly structured approach to learner control, perhaps involving games, may offer an essential environment of meritocracy; also, these environments may offer an indirect approach to attaining learning outcomes, but a direct approach to attaining greater proficiency to learn what is needed to achieve other valued goals.

The TICCIT story about navigational maps with valid progress feedback shows that measurement of learning progress with deep validity is a high goal, difficult to achieve. Valid measurement depends on theory-connected interpretations. Validity of inferences drawn from progress measures and goals lies in the interpretations and actions, not in the numbers produced by the online measurement process. If constructed properly, navigational maps can provide feedback within an interpretive framework fully understandable to the learner. Within this framework, learners can identify their location in a learning domain and

determine where to move next. It is very hard to put together the tools and resources in hardware, software, and implementation that came together for a brief moment to produce TICCIT. Thus, whether the type of measurement-based navigational maps and other tools will work as hoped is uncertain. Can a deeper conception of progress maps be implemented with navigational controls designed for learning proficiency in well understood learning domains? Will these tools enable learners to attain proficiency and motivation sufficient to use learner controls adroitly enough to select the best options for immediate and longer-term progress? Perhaps another generation will find the answer.

The third TICCIT story involved differentiated staffing and cycles of improvement in competency-based environments. Both during TICCIT and later, successes in implementing differentiated staffing models have

been attained. Design-experiment-like changes over cycles should replace premature evaluations of innovations. This form of data-based improvement based on promising models and theories can lead to the large effect sizes that the TICCIT designers hoped for. The design experiment presented in this article did occur with TICCIT within two years of the ETS evaluation. The principles it taught, however, can be effected with a variety of types of systems that integrate technology with learning. Large effects are possible with well-designed and executed implementations of what CAI has become. Successful implementations will involve role differentiation for students and teachers, and will involve integrative projects that both stretch students, and measure their progress toward high, educationally valuable, and intrinsically motivating learning challenges.

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# Patrick Suppes

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Patrick Suppes has published widely on educational uses of computers and technology in education, as well as in philosophy of science and psychology. Much of his research has been focused on detailed physical and statistical models of EEG- and MEG-recorded brainwaves associated with processing of language and visual images and continued development of computer-based curriculum in mathematics, physics, and English.

He is a member of the National Academy of Education (1965), the American Academy of Arts and Sciences (1968), the National Academy of Sciences (1978), and the American Philosophical Society (1991). He has received the American Psychological Association's Distinguished Scientific Contribution Award (1972), the National Medal of Science (1990), Lakatos Award Prize, London School of Economics (2003) for his 2002 book (*Representation and Invariance of Scientific Structures*), and the Lauener Prize in Philosophy (2004 Switzerland).

Currently, Suppes directs the Education Program for Gifted Youth (EPGY) at Stanford University, which offers online courses in mathematics, physics, and English to pre-college students of all ages, with approximately four thousand part-time students worldwide. The program recently added the creation of an online high school whose first students started in August of 2006. Suppes is also doing research on the brain, with emphasis on language and visual images.

