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Articles

machinations from the editor

Although ‘machinations’ sounds menacing, I like its secondary meaning a lot: an artful design intended to accomplish something. In this case the production staff, proofreader, and art directors just spent the last few months self-consciously constructing the next revision of the journal. Our goals were to incorporate more air & light, to imagine more pleasure for you as you read, and to offer a theoretical panorama which keeps you up-to-date on the trends in constructing, evaluating, and re-thinking technology studies as a theory and as a practice, often in the classroom, sometimes the industrial laboratory , or at the desks of technologists and designers.

In this issue, we feature ideas of people from around the world, notably, France, Finland, England, the United States and the Netherlands. What emerges as I read about our practices in technology studies is the ascendance of distance education; the value of alternative assessment strategies (for example, portfolios); the value of technology’s emphasis on the hands/mind connection, especially for students usually marginalized in word–based classes.

And we offer two thoughtful essays about the implications for transferring technology into cultures when the people within that culture are indifferent to its ultimate usefulness. Another philosophical essay asks us to revisit the works of two theorists who have rocked our psychological and educational worlds: Piaget & Vigotsky.

As I continue to talk with you about technological issues that will genuinely affect the tempo & grace of our lives, please let me know two things (1) tell me when an article hits the mark and (2) offer me clues about what else you’d like to see happen here. Also, our web site is truly under construction, before we go live, let me know what you wish we’d make available to you online. I’d be delighted to hear from you: cecei@aol.com.

ce ce iandoli, editor

p.s. special thanks to tim & briar & amy who rushed.

Revisiting Piaget and Vigotsky: In Search of a Learning Model for Technology Education.

Pierre Vérillon

Technology education has always aimed at forming knowledgeable adults, responsible citizens, and capable professionals. Among its central objectives are:

– Familiarizing pupils with the concepts, artifacts, and skills in a given domain of human achievement;
– Enabling pupils, through a cultural approach of that domain, to give it meaning and sense;
– Giving pupils a basis for grounding their future vocational choices and acquisistions; and
– Contributing, through the specific forms of cognitive involvement required by that domain, to the pupils' general intellectual development.

This article focuses on the last objective of education: cognitive development. Drawing upon Mitcham's (1978) observation that technology education achieves its objectives via a concern with making and using artifacts, I examine here the relationship between cognition and the use of artifacts in technology education. The idea is to try, from the context of technology education in France, to contribute to a fuller understanding of human-artifact interaction in order to provide more information and further guidance for curriculum design and delivery in technology education.

Epistemological and Psychological Status of Artifacts in French Technology Education

Technology education was first introduced into the national general education curriculum for French middle schools (pupils aged approximatively 13 to 15) in the early 1960s and has been present ever since, although under different forms (Lebeaume, 1996). In this first section, an attempt is made to trace the underlying evolution in general philosophy behind curriculum change during that period and to see how it affects the status of artifacts as didactical objects. Roughly three periods can be distinguished within this evolution. During the initial phase, technology was essentially taught by physics teachers. Curriculum design and curriculum delivery were, however, closely supervised by the influential technical education hierarchy which, within French public education, is in charge of separate technical and vocational school systems. Nonetheless, policy was that technology should be strictly general education and any vocational connotations were avoided. Consequently, the emphasis was non-artifact based, not making or using learning. Curriculum centered on an analytical, logical, and experimental approach of artifacts that were dominantly referred to as "technical objects." Textbooks presented elaborate theoretical fomalizations of morphology, function, and kinetics. While this described the scientific status of technology, it contrasted with the triviality of the devices-essentially mechanical-actually studied in class (e.g., the notorious door-latch, which left its brand on a whole generation of teachers and pupils). From the cognitive point of view, this first version of school technology clearly tapped the rational and abstract capacities of pupils, very much in the way that a science course could have.

In 1977 this first period ended with a dramatic shift in the official policy relating to technology education. Government and management had become gravely concerned about what they viewed as a general disinterest among young people in industry. Also school was seen as laying too much value on abstract knowledge and skills at a time when it was thought that increased automation would lead to a general "deskilling" of jobs. A sweeping educational reform was undertaken, and for the first time technology, renamed "manual and technical education" (EMT), became a mandatory four year subject for all pupils from 11 to 15 years of age. The stress was on acquiring a basic technical vocabulary; becoming familiar with technical plans, graphics, and drawings; and learning practical procedures such as analyzing a structure, relating an element to its function, organizing one's work space, rationally using tools or machines, being observant of method, precision and safety. Typical tasks were mostly of a domestic nature, such as laying wallpaper, plumbing and electric maintenance, or changing a window pane. However, pupils were also involved in woodwork and building coat hangers or mailboxes. In later years, plastics and electronics became frequent components in school production. Teachers of subjects such as handicrafts and housecrafts, which had been removed from the curriculum, were retrained for EMT, and new teachers were also recruited. Official rationale insisted on the importance of practical, concrete intelligence and manual skills as opposed to the more conceptual, abstract forms of cognition required for other school subjects, and low achievers were explicitely expected to benefit from EMT.

In the early 1980s, policymakers realized that the advent of new technologies in the workplace resulted in a demand for higher qualifications, rather than requiring fewer skills. Manual and technical education (with its emphasis on manual and craft skills) appeared to be completely out of sync with the emerging high-tech forms of management, production, and marketing. In 1985, technology education was completely overhauled. EMT was dropped and replaced by the new subject 'technology', which became mandatory through the four years of middle school. This was accompanied by an unprecedented effort by government regarding school equipment and teacher training. Technology classrooms were decked with computers, robots, and numerically controlled machine tools. For the first time, a new corps of specialized teachers was created and trained. Teachers of the former EMT underwent an intensive one-year retraining program.

Besides the emphasis on familiarizing pupils with advanced technology, the new curriculum, which essentially is still in effect today, stresses that pupils should be able to relate school activities to actual industrial practice. This is generally achieved through the "industrial project method" in which groups of pupils simulate 10 phases-from initial market study to final waste disposal. This sequence, meant to mimic the industrial production process, enables pupils to develop skills in negotiation and organization, varied complex problem solving, and both traditional and high-tech tool use. They also become familiar with industrial concepts and models. Noteworthy is the attention granted to marketing constraints. In many cases the method has led to stereotyped situations and routine activities that have recently come under widespread criticism. The curriculum is currently being altered in order to provide for more variety in the simulated industrial situations. Also, a number of conceptual and instrumental attainments have been redefined.

In each of the three periods that I have outlined, the status of artifacts as didactic objects varies. During the first period, technology education essentially saw artifacts as objects of study. The word 'technology' in French, implies an erudite discourse about the knowledge of techniques. During the EMT period, artifacts were embodied both by the handcrafted one-of-a-kind works made in class and by the material and graphic tools used to make them. developing skills with tools was a major objective and explicitly sought.

During the current phase, the characteristic role of artifacts is as industrial and marketable products. In the latest directive released in 1998, however, pupils are also expected to develop instrumental competencies with measuring instruments, fabrication equipment, and graphic means of representation. Such contrast in curriculum content and orientation during these successive changes certainly reflects instability in the social expectations regarding technology education's contribution to education and child development. It also reflects both uncertainty as to the epistemological status of technology and the lack of a coherent model of student cognitive functioning and growth in technical settings. Blame for this situation cannot be entirely placed on policy makers and educators. Anthropologist M. Godelier (1991) and historian J. Perrin (1991) have pointed to insufficient fundamental scholarship on technology and pleaded for an increase in interdisciplinary research.

Piaget, Vygotsky, and Artifacts

The same can be said about the psychological approach of human technical functioning. In this section, the relevance of two different conceptual frameworks is discussed in relation to modeling human interaction with artifacts. In Europe, during the first half of the century, several contrasting theoretical paradigms competed to explain human psychological behavior. Among these, one important current stressed the role of culture and society in the shaping of mental functions and processes and sought to articulate psychology within the wider realm of anthropological studies. Tool use, techniques, and work as fundamental dimensions of human activity were prominent topics for research. Some of the most influential psychologists of the time–Köhler, Vygotsky, Guillaume, Meyerson, Wallon, to mention a few– were major contributors of empirical evidence and theory. After WWII, however, scientific norms for psychological research favored methodologies and theoretical models inspired by the natural sciences and, later, by artificial information processing. Consequently, interest for complex and holistic, culturally determined behavior (which could no longer be treated as such) waned, and the authors and the tradition that had once tackled these problems receded into near oblivion.

Piaget

In France, Piagetian constructivism is the dominant psychological model that inspires educational theories of learning. One of the appealing features of the model to educators is its cultural, constructivist postulate. It is through action upon the outside world that humans are seen to generate both their cognitive structures and their knowledge. Cognitive structures are the more or less stable forms, that at a given stage of development, underlie a class of similar actions (e.g., the early grasping reflex, later, the prehension scheme, still later, mental manipulation). Knowledge is basically the awareness of the invariant properties of things (through the process Piaget calls empirical abstraction) and of the invariant properties-especially logical properties-of action (through reflecting abstraction). “All knowledge concerning reality ... results from actions or operations upon it which make it change thus revealing its stable and variational properties” (Piaget, 1980, p. 222). Cognitive growth can be represented as a spiral-like process: Interaction with some part of reality sets off an assimilation process ; existing structures are applied to the outside object. Either they are adapted and assimilation is successful or they fail. This creates a situation of cognitive imbalance that triggers accommodation. Through accomodation, cognitive structures are modified to take into account the resisting aspects of reality. Growth becomes a process resulting from the recurrent destabilization of the existing structure by novel and unexpected features of world objects, followed by the subsequent generation of a more powerful structure giving access to deeper reaches of the unknown, which eventually resists assimilation, and so on. Piaget, whose main concern was epistemology and who considered child psychology as an ideal testing ground for epistemological theory, saw this as a very general process, not limited to individual human cognitive growth but underlying, at one end of the development scale, biological evolution and, at the other end, the historical genesis of scientific knowledge.

However, he also very consistently stated that his work in psychology was restricted to what he termed the epistemic subject., that is, literally, a construct of the subject as a producer and processor of knowledge. Since the 1970s, when human problem solving emerged in the United States as both a new domain and a new paradigm in cognitive research, this focus on the epistemic subject has appeared as a limitation to some theorists. Inhelder and Cellerier (1992) pleaded for attention to what they call the pragmatic subject, claiming that if epistemic transformation-the alteration of the world for the pupose of generating knowledge-has been thoroughly researched in psychology, such is not the case concerning pragmatic transformation, in which knowledge is put to use for the purpose of altering the world.

Pragmatic transformation clearly embodies a caracteristic aspect of technology, and a theory of the pragmatic subject would certainly be welcome for technology education. Yet, this area of neo-Piagetian research appears, up to now, to have yielded only scant, even if interesting, results. One of the reasons may be that the Piagetian paradigm, because of intrinsic features, cannot be generalized to the study of the pragmatic subject. Pragmatic transformation in everyday situations departs from biological interaction with the world (such as animal interaction) in that it involves technical mediation-tools and corporal techniques. On the contrary, Piaget has always assumed a fundamental continuity between biological adaptative processes and higher forms of cognition. As a consequence, his model of interaction always boils down to a basically dyadic, face–to–face relationship between organism and environment, thus excluding any idea of mediation. This is, of course, true of other psychological models. As Norman (1991) pointed out, most of our scientific knowledge of human cognition focuses on the "single, unaided individual, studied almost entirely within the university laboratory" (p. 18). He also signaled the difficulty of "integrating artifacts into the existing theory of human cognition" (p. 18), notably because their approach cannot be undertaken within the restricted subject-artifact relationship. The appropriate unit of analysis in such situations, he claimed, is "the total system of human, task and artifact" (p. 19).

Vygotsky

Very similar views had been expounded by Vygotsky (1930/1985) more than half a century ago. Among the early advocates of a cultural approach of cognition mentioned earlier, he developed the most consistent and elaborate conception of the role of instruments. He radically criticized Soviet reflexology, Anglo-American associationism, and Piagetian genetic psychology-paradigms. Vygotsky felt these theories illegitimately "reduce complex superior psychic processes to natural processes and disregard the specific characteristics of the cultural development of behavior" (p. 27). He claimed that "alongside the acts and processes of natural behaviour, it is necessary to distinguish the functions and forms of artificial or instrumental behaviour" (p. 40). He argued that the introduction and use of instruments bring about far-reaching changes in cognition: "It activates a whole series of new functions linked to the use and control of the instrument selected; it replaces and renders useless a considerable number of natural processes, the work of which is developed by the instrument" (p.42).

Development is therefore seen as the result of a largely artificial process in which the mediation of instruments plays a leading role: The central point of our psychology, Vygotsky claimed, is mediation. Through artifactual mediation-both material and semiotic-human cognition engages in relationships with the material and social environment that are fundamentally different from nonmediated relationships.

It has been suggested (Rabardel, 1995; Vérillon & Rabardel, 1995) that one reason for this difference stems from the whole set of novel and specific possibilities and constraints that instrumented activity imposes on cognition. On the one hand, due to the mediation of instruments, the register of enabled action is enhanced in scope and in nature, opening new areas of potential development notably through access to novel means of action as well as to phenomenal and transformational properties previously out of reach. On the other hand, cognition is also oriented and brought to bear on specific structural and functional aspects of instrumented action. The activity required by mediated action is constrained both by artifact structure and the conditions linked to the specific nature of the transformations it enables. These constraints lead to generating artifact-specific forms of information retrieval and processing, of conceptualization, and of mental and motor skills. This tension between new enabling possibilities and new constraints is reminiscent of the Piagetian assimilation-accommodation cycle, but it differs considerably in that it cannot be represented by a dyadic model of interaction. In the following section an interaction model is proposed that provides a place within the classic subject-object relationship for an intermediary element: the instrument.

Towards a Psychological Model of Instruments and Instrumented Activity

Definitions: instrument, pragmatic, epistemic and semiotic interaction

An instrument is any object that a subject associates with his or her action in order to carry out a task. In most cases "instrumented" activity, this object is an artifact (i.e., a made object–such as a tool or a machine–that has been designed for a specific task.) However, natural objects-such as stones, sticks or even parts of the body-can be used as instruments. Also, artifacts are brought into play to perform actions for which they were not initially intended (e.g., using a wrench as a hammer), which shows that use is relatively independent from artifact design.

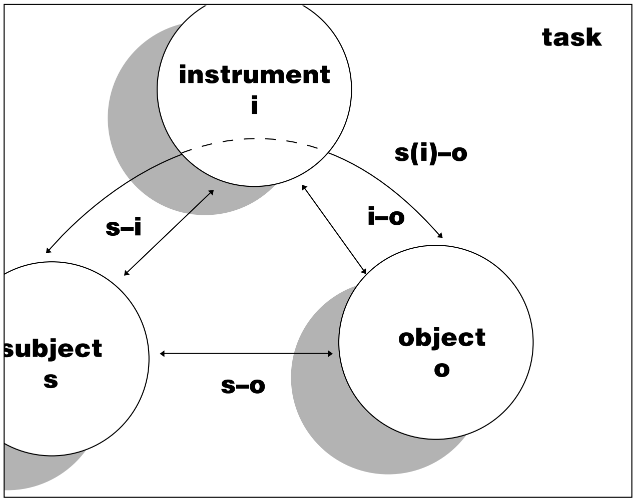
Instrumented action can be broadly distinguished according to whether it aims at producing transformations or affording knowledge. In technology education, instrumented actions (with tools or machines) generally aim at carrying out an anticipated transformation of some part of the environment in order to impart to it new desirable properties, consequently enhancing its value. Using Inhelder and Cellerier's (1992) terminology, such action can be termed "pragmatic". Bringing about transformations is, however, not the only purpose of instrumented interaction with the material environment. Artifacts (such as sensors, meters, for example) are also used to derive knowledge concerning the environment by detecting, registering, and measuring some aspect of reality not immediately accessible to the user. In this sense, this type of interaction is epistemic. Another distinction concerning instrumented activity in technological settings reflects the fact that action is not only directed towards objects but is also directed towards persons. Action in such situations can be seen as aiming at altering another subject's state of information. Communicative action is of this type, and industry requires the use of a wide array of verbal, gestural, and, especially, graphic codes. Such instruments may be designated as semiotic instruments. Of course, semiotic interaction may have either pragmatic or epistemic purposes.

As a matter of fact, instrumented activity whether material or semiotic usually comprises both pragmatic and epistemic phases. For example, a radar-monitoring task is dominantly epistemic, but it requires tuning, which is pragmatic. Inversely, a drilling task is essentially pragmatic, but variation in sound and vibrations during operation provide epistemic feedback concerning the ongoing transformation. Mountain climbers use their ice axes pragmatically to keep balance on the slope or to cut steps in the ice, and epistemically to measure snow thickness or to probe a crevice. They can even use their axes semiotically by planting them on the mountain top to signal their success to onlookers. In this instance, a single artifact serves as several instruments in different situations. In other instances, artifacts may be available but no instruments are elicited, such as when one is unable to operate an unfamiliar device or when archeologists or antiquarians come up with artifacts they no longer know how to use.

The point is that the instrument is a psychological construct distinct from the artifact. More exactly, the artifact, as a material or semiotic construct, is only a partial component of instrumented action. The other component is manifested by the complex set of representations, knowledge, mental operations, and motor skills that are brought into play by the user during operation. So that, in the words of Rabardel (1995), instruments are actually a two-fold entity-artifactual and psychological. Experience shows that instrumental genesis-the construction of such an entity-can be a drawn-out and difficult process. Appropriation is a word that describes the process by which an artifact becomes an instrument. It indicates the two directions in which this process takes place: towards the self and towards outside reality. The first meaning of appropriation requires the artifact to be integrated within one's own cognitive structure (e.g., one's existing representations, available action schemes, etc.) that in general, require adaptation. Rabardel termed this self-oriented construction "instrumentation." The second meaning indicates that the artifact has to be appropriated to an outside context. Specific ends and functional properties-some not necessarily intended by design-are attributed to it by the user. Adjustments are made to account for goal and operating conditions. Rabardel called this "instrumentalization."

The model in Figure 1 highlights the intermediary status of instruments in situated instrumented activity (SIA). Unlike the usual dyadic modeling of subject-object interaction, it underscores the multiple relationships that, in instrumented activity, bind together the subject, the instrument, and the object towards which instrumented action is directed. It shows that anlysis of such activity must take into consideration not only direct subject-instrument (s–i) and subject-object interaction (s–o) but also instrument–object interaction (i–o) and indirect subject-object interaction through the mediation of the instrument (s(i)–o). The task is shown as a back .ground to instrumented activity to indicate that instrumented action is always situated. The task is what gives meaning to the situation.

Figure 1. SIA Model.

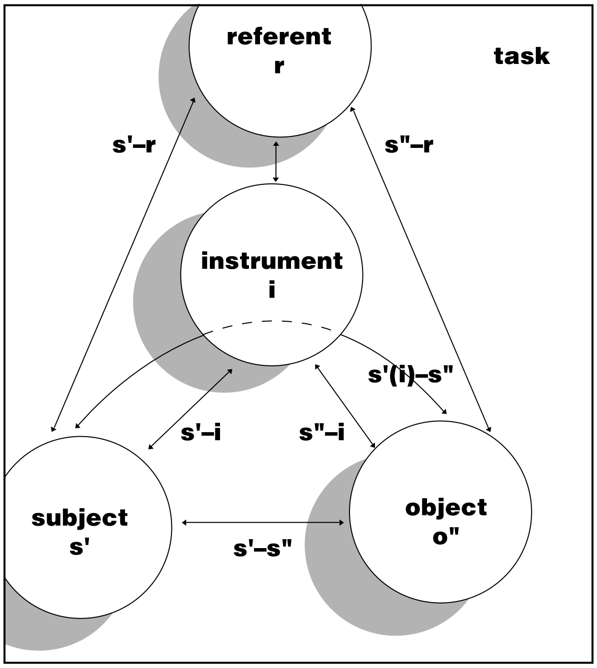


Consider middle school pupils familiarizing themselves with a hitherto unknown artifact, a lathe on which a cylindrical workpiece has been mounted (Vérillon & Rabardel, 1995). They have been asked to imagine the procedures to produce a smaller diameter cylinder using the machine. Their attention and first manipulations initially focus on the transversal and longitudinal handwheels. As they explore features of the lathe, they are likely to call upon prior representations and experiences with similar features with other artifacts (notably toys). Moreover, handwheels, by their very design, tend to elicit a certain specific and relevant type of manipulation (an example of what was referred to earlier as the constraints of required activity). Manipulation of the wheels causes the slide-rest to move and leads pupils to identify the possibility of directing tool motion. Coordination of the two wheels in order to obtain control of tool displacement requires a bit of time. Within the framework of our model, all this process involves mostly subject-artifact interaction. Attention is then drawn to tool-workpiece interaction (instrument-object interaction). A number of pupils initially view this interaction in terms of abrasion__metal cutting doesn't seem plausible to them. Their procedure consists of using one wheel to bring the tool in contact with the rotating workpiece and then, very slowly, with the other wheel, "wearing away" (their terms) matter along the part. Their fear is that uneven spreading of wear may result in an uneven cylinder. When asked how a tapered form might be obtained, these pupils suggest progressively longer wearing periods towards the extremity of the piece.

This example is illustrative of instrumental genesis. At this stage, these pupils have each constituted a similar instrument. A joint instrumentation–instrumentalization process has taken place that can be described in the terms of the model. Prior s-o interaction has led these children to form representations of metallic properties ("it's hard") as excluding any possibility of radical alteration such as cutting. Enabled action by the lathe (i-o interaction) is therefore seen in terms of wear or abrasion, which seems a "softer" approach. The subjects' actions (s-i and s(i)-o interaction) are consistent with this representation. They consist in bringing the tool into contact with the workpiece and monitoring the distribution of wear along its surface so as to obtain the desired shape. Of course this instrument eventually evolves. Dissatisfaction and/or discovery of new properties in the artifact or the object leads to change– generally interdependent– in instrumentation and instrumentalization. Progressive awareness that action with the longitudinal handwheel leaves tool–workpiece distance invariant is important headway and is often tied to the emergence of cutting as a possible transformation.

The SIA model has also been accommodated to apply to semiotically instrumented situations. Vygotsky (1930/1985) referred to semiotic instruments (symbols, codes, maps, drawings, etc.) as "psychic" instruments. "The psychic instrument basically differs from the technical instrument in the direction of its action." [Contrary to the technical instrument] the psychic instrument doesn't produce change in an object; it aims at influencing one's own, or someone else's, psyche or behavior" (p.43). Consistent with this view the model represents interaction as taking place between two subjects: a "transmitter" and a "receiver." Also, since semiotic instruments aim at modifying a receiver's information or its representations, a fourth element has been introduced in the SIA model: that about which there is information or representation-the referent (r). The referent is the object to which the transmitter's instrumented action on the receiver refers. The model consequently shows the two-fold function of semiotic instruments: a function resulting in the sensory and cognitive stimulation of the receiver and a referring function that enables relating to an external object. In other words, in semiotically-instrumented situations, mediation is two-fold: mediation of action of the transmitter upon the receiver and mediation to an object of reference

Figure 2. SIA Model for Seniotic Instruments.



common to both. A new set of relationships can be examined through this model. Instrument-referent relations (i-r) concern coding, that is, the semiotic solutions through which signified information concerning the referent is linked to signifiers (perceptible signifyng units within a given code). Subject-referent relationships (s'(i)-r and s"(i)-r) indicate a subject's relation to a referent object during coding and decoding. Direct s-r relationship points to knowledge, representations, and actual, virtual, or remembered perceptions that s' or s" may have of the referent object.

This model has been used both for the analysis and the design of instruction in technical communication graphics, notably engineering drawing. It has been useful for focusing on certain aspects of technical graphic codes. For example:

–the intersubject relationship during the communication process (involving s'-s", s'-i, s"-i, s'(i)-s" and s"(i)-s' interactions). Subject interaction raises questions such as the nature of information, indices and symbols, and the need for common codes.

–the relationship between subjects, task, and referent (s-task, r-task, and s-r relationships): Technical tasks involve subjects with specific artifacts about which they need specific task-relevant information. What is at stake, at this level, is establishing descriptors of referents consistent with task demands (for example, the need for morphological and dimensional information in fabrication situations).

–the relationship between task, referent, and the semiotic properties of technical codes (r–task, s–task, r-I, and s(i)–r interactions). The structural characteristics of semiotic artifacts, just like those of material artifacts, can be related to the functions they are designed to carry out. The particular features of a given graphic code can be presented (notably to students) as specific solutions designed to convey specific information relating to a specific class of referents centered on a specific class of tasks.

The Psychological Basis for Instruction and Learning

In order to do their jobs, technology educators need epistemological and psychological frameworks to derive coherent representations encompassing their field of knowledge and their students' cognitive functioning. Such frameworks also help them to justify the importance of their teaching to students, parents, plus, teachers of other subjects. This is particularly true in France, where a centralized education system and a national curriculum favors strong disciplinary identity. In order to conceptualize their specific domain, teachers in disciplines relating to technology can rely on centuries of learned reflection within their academic community. In order to better understand their students' difficulties as well as their accomplishments, they can also benefit from the immense work of Piaget and his followers who minutely studied "the construction of reality in the child," as one of his influential books was titled. Piaget's "epistemic subject" can be seen as a model of how human understanding copes with the indistinctly made or natural world. Very much as a scientist, every child experiments and probes her environment in search of logical coherence. This work has produced a valuable framework for the comprehension of learning in mathematics and science education settings, and it is tempting for technology educators to look in that direction for a model of cognition in technological settings.

However, technology is concerned with making and using artifacts, and a purely epistemic approach would miss this essential dimension. An alternative model has been proposed, seeking theoretical guidelines in both post–Piagetian authors and the Vigotskian tradition. The former provides insight sin about "pragmatic" theories about cognition. Thus, action is not oriented towards the production of knowledge as in Piaget's conception. Rather, knowledge is activated and processed by the subject to elicit utilitarian transformations of his or her environment. This provides a basis for a psychological model of instrumentation, that is, a model of the cognitive process in which artifacts progressively acquire instrumental value and are integrated into one's mental and physical interaction with the world. Addressing these two dimensions, the pragmatic and the instrumental, seems quite crucial if we are to afford teachers a better understanding of cognition in technological contexts.

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Web-Based Portfolios for Technology Education: A Personal Case Study

Mark E. Sanders

A portfolio is a collection of work designed to communicate in various ways about its creator. Art and design professionals have long used portfolios to display their best work for a variety of purposes: to show off their work to prospective employers when seeking admission to colleges and universities; in preparing grant proposals to funding agencies; or seeking approval from a prospective gallery. In addition, art and design educators have long made use of student portfolios for assessment purposes.

The current educational reform movement has generated a frenzy of interest in authentic assessment. As a result, the portfolio has emerged as one of the primary experiments in alternative assessment at every educational level (see, for example, Collins and Dana, 1993; Gordon, 1994; Paulson, Paulson, & Meyer, 1991; Wiggins, 1989; Wolf, 1989). These education portfolios have generally been conventional in nature-containers such as notebooks and folders filled with student work, intended primarily for assessment purposes. In more recent years, portfolios have “gone digital,” such as floppy disks on which students store their assignments (Milone, 1995; Moersch & Fisher, 1995; & Niguidula, 1997).

Portfolios do, in fact, provide an excellent tool for assessment. This alone would be reason for more widespread use of portfolios in technology education. But the benefits of portfolios in technology education go well beyond assessment, particularly if the portfolio is conceived of and executed as a Web-based portfolio. Web-based portfolios provide an excellent avenue for “Webworking” (Web page/site development), an area that is not yet, but should be, prevalent in the technology education curriculum.

In the spring of 1995, I began experimenting in my Graphic Communication II class with Web-based portfolios.That semester, I required my communication technology students to represent their course work in a portfolio displayed on the Web. I provided basic instruction in Web page design and development fundamentals and technical specifications, but consistent with Gordon (1994), I intentionally left the details of the execution to the students, rather than provide them with a rigid format. This enabled them to construct and reconstruct their concept of a portfolio as they saw fit-an approach in step with contemporary learning theory. I discovered that the process of designing and producing Web-based portfolios is an exceptional learning experience for students in a variety of ways. This article details the context and findings from this personal case study and offers recommendations and a rationale for the use of Web-based portfolios throughout technology education.

Portfolios in Technology Education

Portfolios and documentation are not really new to technology education. Graphic communication/communication technology teachers have historically required portfolios to display photographs and printing samples, and more recently computer graphics, storyboards for multimedia, and so forth. Students in materials and processing and manufacturing courses have routinely documented their work with such items. Moreover, technology teachers have often required students to document their procedures and final products for assessment purposes.

Over the past decade, instructional method in technology education has shifted from the project method to the technological problem-solving method. The latter, often referred to as design and technology, involves substantially more of the design process and a corresponding increase in the amount of documentation required throughout all stages of designing, constructing, and evaluating solutions to technological problems posed. As a result, conventional portfolios have increasingly been used as a way of documenting and displaying student work in the field. Hutchinson, Davis, Clarke, and Jewett (1989) provided a detailed overview of the conventional design portfolio and discussed its purpose, structure, and potential in technology education.

A Web-based portfolio is a transformation of the conventional portfolio to a format that may be displayed on any computer or accessed via the World Wide Web. The development of a Web-based portfolio offers such an array of learning opportunities and benefits that it now makes sense for nearly every student in technology education to develop a Web-based portfolio and continue to add to it in all subsequent technology education classes.

Why Web-Based Portfolios?

The information age is not just a cliché-we're living it! Global networked information systems such as the World Wide Web are changing nearly every aspect of our lives. These technologies should be prominent within our curriculum. Often, they are not. Web-based portfolios offer a meaningful way for technology students to gain a thorough understanding of these critical new technologies beyond mere Web research.

Web-based portfolios provide benefits that can never be realized with conventional portfolios. One vitally important benefit to the future of our profession is the Web and its potential to illustrate the outcomes of technology education programs-especially to those beyond our profession. While the Web is indeed a global medium, the most important audiences are much closer to home: parents, fellow teachers, administrators, and local educational decision makers. We want them to know what technology education is, and there is no better way than to share with them "authentic" evidence of what students are learning and doing in technology education classes.

The Web offers new ways of displaying our work. Conventional portfolios are fine for conventional materials-sketches, drafting, printed materials, and photographs. But the Web allows us new options such as animation, navigation, digital audio/video, virtual reality, and interactivity. In comparison, conventional portfolio techniques limit what's possible.

Everything we create in technology education may be displayed on the World Wide Web, whether it originates in the communication, production, or the energy/power/transportation component of the curriculum. Digital graphics can go straight to the Web. Three-dimensional prototypes may be recorded with a digital camera and displayed on the Web within minutes. Projects/solutions with moving parts may be videotaped, digitized, and converted to Web-viewable formats-such as animated GIFs or digital video. Digital video (DV) camcorders now make it remarkably simple to create digital video, and technologies such as Apple's QuickTime and RealNetwork's streaming software make video display on the Web an increasingly viable option.

There are no compelling reasons why technology education should not be taking full advantage of the opportunities that Web-based portfolios provide. Technology education should be leading this effort in our schools.

Findings

Teaching and Learning

In the spring 1995 semester, I provided students in my Graphic Communication II course (the second in a three-course sequence) with the option of developing a Web-based portfolio. Two students accepted the challenge and created handsome displays of their course work. I was impressed with how much they learned in the process and how well these portfolios communicated about what they had studied in the course. I had provided the basic fundamentals through conventional instruction, and they learned some "tricks" on their own from resources on the Web, as there were relatively few other sources of information at that time.

That fall, with the assistance of one of my undergraduate students, I established a Web site for the technology education program at Virginia Tech. Initially, it fit on a single floppy disk, though it now consumes several gigabytes of server space. Over the winter break, I set up a Web server to house our new Web site and the student portfolios that I now required (Sanders, 1996). The server proved to be relatively easy to set up, providing both my students and me with a host of new learning experiences. Among other things, students learned to upload data to the server with the FTP (file transfer protocol), basic server set-up, and a good bit about cross-platform compatibility. In short, they began to learn how networked information systems work (Sanders, 1999).

Given these initial successes with Web-based portfolios, I began to require them in my

Communication Technology class the following fall (1995) semester. The experiment continued to go very well. About 20% of the students seemed to get "hooked" on the possibilities the Web provided. That very first year, one student created a virtual reality (VRML) component for his "frames" formatted portfolio and included such things as midi audio segments and Java scripts. These were state-of-the-art capabilities at the time, supported only by the latest browser version. I did not teach those tools; he discovered and perfected them on his own. Students immediately began to create Web-based presentations for their in-class presentations in lieu of the more conventional PowerPoint presentations I had been requiring in class. Some students also began making Web-based presentations in other classes when called on to make presentations.

During the semester, students present their Web-based portfolios in class and their classmates and I provide both written and verbal feedback. These reviews cause students to reflect upon their work and upon the structure/aesthetics of their portfolio. Gordon (1994) and Porter and Cleland (1995) have discussed the value of peer feedback and reflection in the development of conventional portfolios. Students have an opportunity to rework their portfolios following these peer reviews, and the results can be dramatic. Moreover, the portfolio presentations often provide students a teaching opportunity, as they explain to their classmates the concepts and technical processes used to accomplish specific aspects of their portfolio.

The Web-based portfolio assignment was rich with problem-solving challenges. Some of the work (e.g., electronic color separations) was difficult to display effectively. Students began to experiment with screen captures, animations, and portable document files (PDF file format) to solve these technical challenges. I began to see the Web as a very powerful environment for the teaching/learning process-better, in some ways, than any I had previously experienced. The Web is the ultimate "facilitative" environment. I discovered, as did my students, that every technological "trick" a student might wish to execute on the Web is documented and often supported (with free tools) on the Web. Thus, motivated students access the information they need to develop innovative portfolios. Some did so voraciously, in a way that I had not previously witnessed in more than two decades of teaching.

In the fall of 1996, I extended the Web-based portfolio requirement "down" to the first course in the Graphic Communication sequence. This allowed students to develop their Web-based portfolios over the three-course sequence, adding to it during each subsequent course. My Web page/site development instruction expanded to include such things as technical and aesthetic design issues, creating and editing PDF files, animations, image maps, frames, copyright, and "fair use" of multimedia. A substantial percentage–perhaps half or more–of my students continue to experiment extensively with Webworking tools beyond those I demonstrate, putting in long hours after class on the assignment.

I continue to extend the offer of free server space (global dissemination) to students whose portfolios meet my expectations for this mode of "publication." People from all over the world regularly access these electronic portfolios from our technology education server (http://teched.vt.edu/).

In April 1999, for example, visitors browsed 15,449 electronic portfolio pages from our technology education server over the course of the month. These Web-based portfolio page "hits" resulted in 61,616 total "requests." Since each graphic on the page represents a "hit," there was an average of 3.99 images/page. This is worth noting, as it gives you some idea of just how "graphically rich" these pages are. Visitors literally get a rich picture of the work our students are doing by browsing these Web-based portfolios. In the process of browsing these portfolios, visitors learn a good deal about technology education and our program. In effect, these Web-based portfolios are the "industrial arts fairs" of the information age.

Elements of a Web-Based Portfolio

A Web-based portfolio is not a "home page"! Home pages that are often required of students in public schools are usually very simple Web pages with links to other "cool" Web pages, illustrated with a variety of "free" graphics copied from the far corners of the Web. Despite the zillions of home pages that have been created in classrooms across America and throughout the world, this exercise is relatively limited in the learning opportunity it provides. There are three fatal flaws to this home page strategy. First, almost no one other than the home page developer is likely to find the linked information to be the least bit interesting or useful. Second, few graphics found on the Web are copyright free, which means the act of copying them to a home page is a violation of copyright law. Finally, there is very little to be learned from creating a list of Web-links and copying/pasting graphics.

Fortunately, there is a very simple solution to all three problems: students should create every component of their Web-based portfolios. By handling the assignment this way, every aspect of the Web-based portfolio-not just the images of class projects-is a demonstration of the student's potential/capability. This simple strategy solves all copyright issues. If students want a nifty animation for their return mail, or a flashy graphic for their main page, or attractive navigation buttons, they simply create these images. That's where most of the learning takes place. With this in mind, the Web-based portfolio might be viewed and characterized more as a learning activity than as an assessment tool.

Web-based portfolios should begin with an original design. In developing their designs, students should review other Web-based portfolios, making note of techniques and design solutions they like. They should also consult some of the many excellent Web sites that discuss and illustrate good Web design as well as conventional literature along these same lines (see, for example, Siegel, 1996; Weinman, 1997; Williams & Tollett, 1997; or any of the more than 25 links found at http://teched.vt.edu/gcc/html/Webtools/WebDesign.html). They should then develop rough layout sketches for each section of their portfolio and a "site map" for the overall layout. A house or a gallery offers a useful metaphor for conceptualizing the structure of the Web-based portfolio; both should have a welcoming entrance/main page that provides convenient access to the other rooms/sections of the building/portfolio.

Web-based portfolios should include a resume or, for younger students, a personal statement. But putting the resume alone online does not constitute a Web-based portfolio. One-line listings on resumes offer a concise way of communicating basic information, but they do not begin to portray the range of accomplishment afforded by the rest of the Web-based portfolio. Listing a class taken or software applications used means little compared to a well documented presentation of a project/solution created in a technology education course.

From the onset, my intent with the Web-based portfolio was to provide a venue so that students might display work from all of their technology education classes. While not a particularly difficult task, this takes considerable time and careful planning. Images and documentation must be created/saved as students progress through their various courses. All work, both digital and conventional, must be converted to Web-viewable file formats. Regrettably, many students do not find enough time outside of class to prepare work from all of their technology education courses for display on the Web. This will change as we increasingly use networked information systems (i.e., the Web and whatever supplants it) throughout the entire technology education curriculum. One day in the not-too-distant future, documenting course work on a network will be as commonplace as storing work in a notebook is today.

The following are some of the critical insights I have gathered since my first web-based portfolio class. Navigation tools (buttons and menus that allow "browsers" to go forward, back, return to the main page, etc.) are very important in portfolios. It is best to design a simple layout for these buttons and links. They should appear consistently in the same place on each page, so the user may find them easily. This simple rule of interface design made the Macintosh remarkably more "user friendly" than the DOS environment of the PC for a decade.

Each piece of work displayed in the portfolio should be accompanied by a brief narrative description of the process involved in the creation of the work. This is very important because, philosophically, technology education is more concerned with understanding technological concepts and processes than it is with the actual appearance of the final product. In contrast to artists' portfolios, which focus almost entirely on the appearance of the work of art, technology education portfolios should communicate the concepts and processes learned in the process of creating the work being displayed. Technology education is for all students, not just for those gifted in graphic design. Narrative descriptions of process accompanying each work displayed helps to underscore the point to those who view these portfolios on the Web that technology education is about technological understanding. Moreover, writing about the concepts, processes, and techniques employed reinforces the conceptual component of technology education for the students creating the portfolios. This documentation of process is often more telling than the final compressed images of the work completed, since students gain an understanding of technological concepts and processes through the hands-on work, even if the final picture of the work does not make an award-winning design.

Finally, portfolios should include an "About this Portfolio" section. This is a good place for students to explain that the portfolio was developed as part of a technology education course/curriculum. In doing so, they should name the teacher, school, and the semester year in which the Web-based portfolio was initiated, keeping in mind that the Web-based portfolio may well continue to develop throughout the students' lifetimes. In addition, students might identify tools used and the unique technologies employed to produce this section of their portfolio.

Copyright protects the creator of any work from improper use by others. Technology educators and students need to be aware that most text, graphics, and so forth found on the Web may not be freely used elsewhere on the Web by all who encounter them! Since the creator has the rights to the work until those rights are formally released-which is generally handled by a written contract-most information encountered on the Web requires permission for fair use.

When students display their own work, they will own the rights, and they will begin to appreciate that copyright laws are written to protect their rights as the creator, rather than as a means to punish copyright violators. If all of the work contained in the portfolio is the student's work, there is not any danger of copyright infringement. For those who feel they must use clip-media, there are a relatively small number of Web sites that offer copyright free images and media. Typically, these sites clearly state that the media is "copyright free," and they provide written permission to use this media right there on the site. For a modest investment, technology teachers may purchase copyright-free graphics, audio, and video, and provide these for student use, thereby solving the copyright dilemma for those students who do not have the time or wherewithal to create their own from scratch.

Invariably, students will find copyrighted material on the Web that they would like to use. The "Fair Use Guidelines for Educational Multimedia" (Subcommittee on Courts and Intellectual Property, 1996) were established to assist educators in making decisions about the use of multimedia for educational purposes. In short, while 10% or less of most multimedia text/images/clips may generally be used in educational presentations, putting these same "clips" on the Web for worldwide dissemination is not considered "fair use." Technology teachers and students should become familiar with these guidelines and share them with their students to avoid unnecessary copyright infringement. The complete set of guidelines is posted on a number of Web sites (see, for example,http://www.libraries.psu.edu/ mtss/fairuse/).

Benefits of Web-Based Portfolios for Technology Teachers and Students

One of the most compelling reasons for employing Web-based portfolios in technology education is the outstanding learning opportunities they provide. Just as woodworking projects engaged students in the tools, materials, and processes of the industrial age, "Webworking" involves students with the tools, materials, and processes of the information age. Developing effective Web pages requires an understanding of a wide range of information age tools-design fundamentals, HTML and VRML (both scripting languages used to construct web pages) Java scripts, digital graphics, digital audio, digital video, animation techniques, and so forth. There are Web-development tools aimed at all levels of expertise so elementary technology education students may begin creating Web pages and continue to learn new and more sophisticated tools throughout their middle and high school years.

The Web-based portfolio assignment begins impacting students in significant ways even before they begin to assemble the final portfolio. Just as writing for publication requires more diligence and considerable revision than does writing in one's diary, the possibility of publishing their work on the Web provides students with additional motivation to do quality work in class. Selecting work for the portfolio involves self-assessment. Planning the portfolio requires students to reflect on their work, evaluate it, and revise it for "publication."

Web-based portfolios offer a good opportunity for teaching/learning design fundamentals. Conventional portfolios cause students to ask and answer such questions as: What is the best way to show off the work? How should the work be ordered and arranged? How might color enhance or detract from the work?

Web-based portfolios require answers to similar questions, but they also provide design challenges that are tempered by the technical specifications and demands of the Web. The opportunities for technical challenges and creative alternatives when developing or converting material for display on the Web are much greater than for conventional portfolios. While basic display of text and graphics on the Web is a relatively simple task, students wishing to go beyond basic Web-portfolio assembly will discover technical challenges as far up the ladder as they wish to climb. Other than the obvious learning opportunities, self-promotion is the primary benefit students will realize from the development of Web-based portfolios. Students may use their portfolios to communicate specific talents and expertise to university admissions officers, scholarship selection committees, and prospective employers. Although providing a marketable skill is not an objective of the Web-based portfolio assignment, significant numbers of students who have created one in my classes have found both part-time and full-time employment as Web site developers.

Goerss (1993) asked middle school students what they liked about creating conventional portfolios. Among other things, students said portfolios helped keep them organized, allowed them to see personal improvement, provided a glimpse of their best work and past accomplishments, and gave them responsibility and choice.

Web-based portfolios benefit technology teachers in many ways as well. Student-developed Web-based portfolios can and should be used to promote what is happening in the technology education program. This can be accomplished by publishing all or some on the technology education program's Web site. Selected images may be compiled into a "gallery" of best work, in much the same way teachers collect and display work at technology festivals.

Technology teachers are increasingly using the technological problem-solving approach, requiring students to design multiple solutions to problems. The Web-based portfolio provides a means of documenting all of the steps along the way in the design process. Portfolios can be a very student-centered activity, particularly for older students who see it as a means of communicating their expertise to others, such as a prospective employer or college admissions officers.

The Web-based portfolio requirement also benefits technology teachers by bringing them "up to speed" with current information technologies. Technology teachers will increasingly face a credibility problem if they do not have basic competence with Webworking tools.

Benefits of Web-Based Portfolios for the Profession

As school systems continue to ramp up to the Internet, it is critical to the future of technology education that our laboratories be included in the school network. Because our facilities are often remotely located within, or even beyond, the walls of the main school building, leaving our facilities out of the network will be an easy way to shave dollars from the networking budget. When and where that occurs-and there is considerable anecdotal evidence that this trend is occurring-technology education will take a giant leap backward with respect to its role and status in education. It is critical that we request/demand network access in our laboratories-and required Webworking is perhaps the best way for us to make the case.

Webworking is becoming a requirement in education. Virginia's Standards of Learning, for example, require all students to be able to create Web pages by the end of eighth grade. This presents an opportunity for our profession. If all middle school technology education students were required to build Web-based portfolios, students could simply enroll in technology education to learn the basics of Webworking. Imagine what this would do for the status/image of the field. On the other hand, if we fail to seize this opportunity, others certainly will.

Since the Web is accessible to nearly everyone in the school and community, and to many across the planet, Web-based portfolios offer unprecedented public relations potential for technology education. Through the Web we can inform/educate parents of our students, potential new students, fellow teachers, administrators, and curious "surfers" about technology education. Given the multitude of ways in which technology education is misunderstood by the public, it is critical that we develop a presence on the World Wide Web, which would help to educate the public about our field (Sanders, 1995). Student portfolios displayed on technology education program Web sites would go a long way toward educating the public and developing such a presence. The resulting influence is global.

Our field has historically used student projects for public relations purposes. The public's image of industrial arts was linked to the tangible reminders of the "take-home" project and public displays of student work that were so common in our field. The public did not learn of industrial arts by attending our national conference or reading our publications. They learned about us when their children built something tangible and brought it home. By seeing the work of our students in Web-based portfolios, parents and the broader public can begin to understand the content, method, curriculum, and purpose of technology education.

Our field needs the exposure Web-based portfolios provide. We need to share our good work with the public-fellow teachers, administrators, parents, and education decision makers. Without their knowledge and support of our work, we will not achieve what we hope to achieve in education.

Webworking Tools

While the intricacies of hypertext markup language (HTML) once limited Web page development to computer programmers, inexpensive what-you-see -is-what-you get editors now make the process more like word processing than programming. These tools make it easy to display and link graphics and text-the essential skill required for creating a Web-based portfolio. An endless array of freeware and shareware on the Web provides inquisitive and motivated students with the tools they need to create almost any effect that's "do-able" on the Web (see, for example, the Web Tools section of GRAPHIC COMM CENTRAL, http://teched.vt.edu/gcc/). So the tools are readily accessible and cost effective.

Though not absolutely essential, it is desirable for technology teachers to operate or have access to a Web server on which they may post student portfolios. Fortunately, most school systems now operate a Web server. But Web-based portfolios are developed off-line and may be saved on any storage medium (e.g., floppy disk, removable cartridge, CD-ROM, etc.) and displayed/read on any computer, whether connected to the Web or not.

In those cases where technology education teachers/students do not have local server support, there is the possibility of mounting Web-based portfolios on a nonprofit server in the community, on a commercial Web server supported completely by advertising (e.g., www.geocities.com), or on a remote server supported by the profession. The Virginia Technology Education Electronic Publishing Project (Sanders, 1997) for example, hosts Web sites for technology education programs in the state. State departments of education or professional associations can and should provide this service for those who do not have local options in this regard.

Closing Thoughts

Webworking is not yet commonly taught in technology education. My sense is that teacher education programs are not generally teaching or requiring Web-based portfolios of their students, and teachers in the field are likewise shying away from this opportunity. A national study of middle and high school technology education programs (Sanders, 1997a) found that about 40% of the programs had no access to the Internet whatsoever, which would help to explain why Webworking has not yet become a widespread practice in the field.

While many modular laboratories incorporate digital communication activities, most that I have visited were ill-equipped with respect to Webworking–or even Web access-perhaps since Web infrastructure/access cannot be sold/shipped with the other modular laboratory components. My work with the ITEA Section for Communication Technology, GRAPHIC COMM CENTRAL (http://teched.vt.edu/gcc/), and in the field leads me to conclude that relatively little is happening with networked information systems and, more generally, with digital communication technologies of all types in more conventional technology education laboratories/programs.

We do live in the information age. Thus, failure to engage our students in meaningful activities related to networked information systems will have negative ramifications for our profession in the future. The Web-based portfolio is an effective way for technology education teachers, programs, and students to become active and savvy participants in the networked information systems that are transforming our society. Technology teacher educators, public school technology teachers, and curriculum developers should therefore move quickly and decisively to incorporate Web-based portfolios into the technology education curriculum. Doing so would benefit the student, the local technology education program and teacher, and the profession at large. It is an opportunity we should not let pass us by.

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Current Trends in Technology Education in Finland

Ari Alamäki

It is an old tradition in Finland to teach a school subject dealing with the use of machines, materials, processes, techniques, and tools. Since 1866, educational *sloyd* (handicraft) has been a compulsory school subject for both boys and girls. Even today in Finnish technology education, which is nowadays called *tekninen työ* in the Finnish national curriculum guidelines, students still design and make products (Kankare, 1997; Kolehmainen, 1997). Comprehensive schools provide compulsory basic education for pupils between the ages of 7 and 16. Education beyond the age of 16 is voluntary, taking the form of either three years of study at a theoretically oriented high school or a two-to five-year course in a vocational school.

The activity of students is concentrated on problem-centered design projects (inventions) that transcend the limitations of materials and techniques. Finnish technology education can be characterized as mainly a design approach that has evolved from the craft-oriented approach . Additionally, it involves elements of the high tech approach, using computers, computer-aided design, and electronics. These tools are often included as either part of design projects or in construction kits.

The national core curriculum and curricular guidelines are very vague; they only provide brief outlines. Although this allows for local flexibility, it also increases the diverse ways in which technology education is taught from one school to another. In the latest national core curriculum (Opetushallitus, 1994), the main emphasis is on the “idea-to-product” process with the pupil fully involved in design. Although designing and making products is a central part of the national curriculum guidelines, they also refer to the need for a broader technological understanding and capability. Student-centered instructional strategies are encouraged by a 16 student per technology classroom limit.

In informal discussions between teachers and teacher educators, technology education typically includes more out-of-date technological processes, such as the making of wood and metal items, than modern technological processes. Studies by Alamäki (1999), Kananoja (1997), Kantola (1997), Lindh (1996), Parikka (1998), and Rasinen (1999) come to similar conclusions. Thus, technology education should be more connected to the modern technological world, although it already covers activities related to computers, construction kits, electronics, electricity, machines, and technical drawing. Technological concepts, such as communication, construction, energy, manufacturing, and transportation should be taught because they are an essential part of students’ surroundings. In fact, students’ projects focus on these key concepts, in a somewhat narrow way. These concepts are rarely reviewed in broad contexts such as global, ecological, and social issues. In this regard one can say that particular approaches and student activities determine the nature of technological knowledge and processes that students learn. The approaches of tasks in technology education determine the kinds of technological knowledge and processes students learn. For example, Autio (1997) found that teaching of design was more sketching and shaping than systematic problem solving.

Technology Teacher Education in Finland

The Department of Teacher Education in Rauma, University of Turku, is the only institute that prepares Finnish-speaking technology teachers with a technology education major. The technology teacher education program enrolls 36 male and female students each year. Åbo Academy at Vaasa, which educates Swedish-speaking technology teachers, has admitted 10 students for its technology education program every fourth year, but beginning fall semester of 1999, seven students will be admitted every second year. Other departments of teacher education also teach technology education, but only as a minor. The University of Jyväskylä and the University of Oulu have recently improved the technology education component of their classroom teacher education programs.

Admission to Finnish universities is highly selective and is usually based on previous performance (e.g., Finnish Matriculation Examination) and an entrance examination. The technology teacher education program has a single entrance selection procedure that includes a written examination, an individual interview, a technological reasoning test, and a practical product-making test. University studies are mainly free and funded by the state. Therefore, students enrolled in the technology teacher education program pay no tuition, except for the compulsory student union fee. In addition, students have to pay for books and other materials. Traditionally, the teaching profession is appreciated in the Finnish society. Many more young people apply to the technology teacher education program than are accepted. Also drop-out rates are very low and students are usually highly motivated, technically oriented, and talented (see Kohonen & Niemi, 1996). Since 1979, all technology teachers have received a master's degree in technology education; teachers in comprehensive school must hold a master's degree from a university.

The University of Turku's Technology Teacher Education Program

In the technology teacher education program at the Department of Teacher Education in Rauma, University of Turku, students are able to take the curriculum for either one or two teaching subjects. In addition to technology education, a second teaching subject, such as an elementary education or mathematics, entitles them to teach in primary school as an elementary or mathematics teacher. The program leads to a Master of Education degree comprising 160 credit units (1 credit unit = 40 hours of work) and accomplishes the aim of the Faculty of Education (1996) which provides that students will:

- Become familiar with the relevant terminology, materials, and technology; be enabled to follow the general development of technology; gain a sufficiently broad mastery of practical work in their field to be able to convey the central knowledge and skills of the subject to their pupils.
- Become familiar with the physical, psychological, and social development of children and young people, with scientific theories and their applications in education, technology education, and the teaching process, thus enabling them as teachers to promote the development of the whole personality of a child or young person and to achieve the goals set their education.
- Acquire the expertise in technology education and education in general that will enable them to master the main basic theories and terminology of education, general didactics, and the didactics of technology education.
- Acquire knowledge of society and the sectors of business, professions, and production, enabling them as teachers to comprehend current situations and changing needs of society, and to use these as a basis for solving and observing problems in their subject in accordance with the requirements of technology and the nature of the work.

In the technology teacher education program, students study a variety of technologies, mechanical and electrical engineering, product design, project studies, research methodology and statistics, educational sciences and ethics, developmental psychology, didactics of technology education, administration, evaluation, and sociology of education. Furthermore, students have to pass four teaching practice periods. Three levels of study comprise the technology teacher preparation:

- Basic Studies: In this module, students learn to apply product design to the solution of technical problems, to choose correct materials, and to apply various technologies correctly, while bearing in mind the need for occupational safety. The integration of various technologies and consumer and environmental education are emphasized.
- Intermediate Studies (Product Project Studies): This module introduces students to (a) the application of special techniques and materials science in production, (b) control and regulation tech-

niques, and (c) mechanical construction. The emphasis is on design work carried out by groups in tasks which involve integration of technology education with the natural sciences and general technology. These require problem- solving skills and technological know-how.

- Advanced Studies: This module deals with technological and pedagogical planning and research of technology education, and with producing, processing, and evaluating new information in the field. The Advanced Studies module begins with theoretical observations of production processes and proceeds to deal with the general possibilities for making use of technology. After planning and implementing a project, students must produce a written report of their evaluation of the process and product (Faculty of Education, 1996).

Students' Projects in Technology Teacher Education

After they have finished their undergraduate studies, most students go on to the master's degree because it is required for a teaching position in general education. During their master's studies, students develop technological knowledge and capabilities through many different product projects. The students' product/project for the master's thesis (15 credit units) is the largest project in the program and consists of a written report and a product. Kolehmainen (1997) stated that this consists of (a) the development of a product which evidences newly generated technological knowledge, (b) applying experiences to teaching which reflect the students' professional growth as a teacher, and (c) critical evaluation and development of students' own practices as a basis to develop new action and thinking strategies.

The product/project is carried out by collaborative pairs and must be innovative, unique, and focused on solving a problem related to the students' life or the needs of a local community or industry. Following the creative problem-solving process, progress resembles a spiral starting with defining a problem, to ideating, selecting the best idea, and making and testing a prototype.

In this process students' learning can be characterized as self-directed, collaborative, and experimental combining both abstract and practical learning. Kolehmainen (1990) found that the convergent learning style is typical for students in the technology teacher education program. Kolehmainen (1997) stated that strengths in the convergent learning style are associated with decision-making skills and the ability to solve problems and to apply ideas in practice. The central aim of the technology teacher education program is to develop such capabilities so that students are able to solve technological problems in authentic and novel situations. Therefore, students develop technological knowledge, metacognitive skills, and general strategies to deal with technology through problem-centered product projects.

The product/project begins with a planning seminar in which students and a professor discuss the needs to be addressed or solved and appropriate methodological approaches. Scientific, technological, and social factors related to the problem are reviewed. Theoretical solutions to proposed problems are considered. More and more students invent, design, and build products that respond to needs of local industry and institutions. Such products are usually associated with industrial production. In addition, local industry sponsors students and gives them competent guidance. Recently, a research and development program to promote collaboration between the technology teacher education program and industry was established and funded by the Ministry of Education and the European Social Foundation.

The written report of about 100 pages that forms a master's thesis is accompanied by a product. It includes a general description, such as the historical, scientific, social, and technological aspects about the field related to the original problem. In addition, the theoretical basics of design strategies are reviewed. The written report must also include a presentation about the students' own problem-solving and design processes and prototype testing. Students must also review their own learning processes and experiences during the product project, including reflections on their own professional growth in this field.

Several examples of students' study projects are described here: Two students designed and built a production line for anodizing small aluminum pieces. A component of the study determined the effects upon manufacturing equipment to the chemical basics and processes of anodizing that impact forming anode-covers on aluminum pieces. Another student-team helped local farmers by designing and building the "frost-guard" that monitors temperature changes in a field and sounds an alarm in the farmer's bedroom if the temperature has fallen below the minimum. Another team made a melting furnace capable of melting such metals as tin, lead, and zinc at low temperatures.

A pupil with communication difficulties needed a communication device in a primary school in the city of Rauma. Students from the technology teacher education program made a device that utilizes the FC-method, which is an alternative practice and communication method based on finger pointing. A team designed and built an engineering shop press in collaboration with a local industrial plant. They had to study ergonomics, work safety, mechanics, and other things to solve the problems. The press is now in use in that industrial plant as are other student-made devices. Although there are many kinds of drawing tables, a team designed and built a multipurpose table for technical drawing, picture-making, photographing, and other leisure hobbies. A linseed oil bottling stand was designed and built by another team. The bottling stand is a movable device equipped with a motorized regulator that controls the device's wheels and the height of its cover. Two students, who are interested in gliding, designed and built a folding towing system needed to launch a glider in fairly flat Finland.

Some Additional Observations

Finnish technology education emphasizes design and making activities because they form an integrated and holistic learning environment, which is flexible according to students' preparedness and learning styles. Furthermore, in Finnish schools and in many kindergartens, a complete workspace, furniture, tools, other equipment, and a long tradition of accomplishing design and making activities already exist. More research is necessary, however, on students' cognitive and affective processes in technology education concerning, for example, the conceptual and procedural thinking processes that design and making activities evoke in students. Without sufficient guidance, students' design and making activities in schools happen in a conceptual and intellectual vacuum, and the nature of the activity changes to one of artistic-aesthetic busywork. Currently the situation is conflicting; in technology education the cognitive content should be increased, but at the same time students demand more and more practical work that typifies busywork, hobby, or therapeutic activities.

In this article the Finnish system was not compared to other countries. In fact, it is difficult to compare technology education or any educational programs because history, tradition, and politics result in different educational systems in many countries. In Finland, as in many other countries, technology education is a school subject with its own identity. Nevertheless, Finnish technology education is still seeking its final shape and value in schools. Although it has been evolving since 1866, considerable effort is still necessary. Furthermore, some educators believe that technology education should be design-process based because of the quantity of new content and educational requirements. Others believe that it should be a more theoretical “classroom-type” school subject. In most countries, however, the main focus seems to be on technological literacy or technological capability focused on the skills needed to cope in the technological world.

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Scientific Visualization for Secondary and Post–Secondary Schools

Aaron C. Clark & Eric N. Wiebe

North Carolina State University's Department of Math, Science, and Technology Education along with Wake Technical Community College's Engineering Technology Division and North Carolina's Department of Public Instruction (Vocational Education Division), sought ways in which to build a strong secondary program in scientific and technical visualization, focusing on the use of sophisticated graphics tools to study mathematics and the sciences. Momentum for this high school-level scientific visualization curriculum developed out of a revision of the complete high school technical graphics curriculum used throughout the state (North Carolina Public Schools, 1997). It became clear that a scientific visualization track could both broaden the scope of the current technical graphics curriculum and attract a new group of students to technical graphics.

For the past four years, educators from North Carolina have met to develop and improve a new sequence of courses in scientific and technical visualization. The main goal of these courses is to teach technical graphics to a new audience: science, technology, technical, and pre-engineering students. The courses are designed to reflect a broader application of computer graphics techniques in the workplace and represents a rich area in which technical graphics teachers at all levels of education can be involved. These new courses complement, rather than replace, more mainstream technical graphics courses in architectural and mechanical drafting currently being taught.

While contemporary high school drafting (technical graphics), technology education, and college programs now use sophisticated graphics tools to create two-dimensional (2-D) and three-dimensional (3-D) wire-frame and solid models, their focus has remained narrow. It is now apparent that changes primarily brought about by advances in technology have created new opportunities to use similar tools to promote and enhance the study of the physical, biological, and mathematical sciences.

These new courses are designed to articulate into scientific visualization and technical graphics curricula at both two-year and four-year colleges and universities through the Tech-Prep initiative. Articulation between schools allows for a broader range of students to have a visual science course count for admission into a college or university. The courses have the potential to replace the fundamental drafting course required for most degrees in engineering and technology.

The proposed student populations taking the scientific visualization courses are traditional vocational track students and pre-college students who plan on studying in scientific, engineering, and technical fields. The graphic tools used in these courses can help students to understand abstract and numerical concepts and understand how these graphic tools are used in the sciences, business and industry, finance, and virtually all major areas of our economy.

Background

Technical graphics have long been recognized as a powerful communications tool by professional engineers, scientists, mathematicians, statisticians, and other technical professionals. The use of technical graphics to convey scientific and technical data and concepts has a long tradition in print media. William Playfair, working in the 18th century, is often recognized as being one of the earliest practitioners of using graphics to communicate technical data to the public at large (Tufte, 1983). More recently, theorists in the 1970s and 1980s began work on a modern basis for technical communication with graphics (Bertin, 1983; Cleveland, 1985; Tufte, 1983). This work, using graphic design, rhetoric, and psychological theory as its basis, attempted to try and understand the appropriate match of information to be conveyed, graphic technique, and audience to be served.

Through most of this period, scientific and technical data continued to be produced using mainly manual methods by professional graphicians. During the 1980s, improved printing and computer technology combined with demands from the public increased the use of technical graphics in textbooks and newspapers. The success of the national newspaper *USA Today* is subscribed partly to its revolutionary use of full-color artwork and extensive use of informational charts and graphs (Brock, 1998). Though now being widely viewed by the public, these graphics were still being produced largely by trained professionals.

The 1980s also brought into use the color graphics workstation. In combination with custom-written programs, graphics workstations were used to produce graphic visualizations of the masses of data being produced by a new generation of supercomputers (Friedhoff & Benzon, 1989; McCormick, Defanti & Brown, 1987). During the period of the late 1980s and early 1990s, individuals began to bring together the technical communication theories of effective graphic communication with the new flexibility and power that computers brought to professionals (Keller & Keller, 1993; Patrikalakis, 1991; Senay & Ignatius, 1990). Still, the audience was professional researchers who could hire staff to program and produce these visualizations on high-end computer technology. In tandem with the development of supercomputing graphics, the desktop publishing revolution brought, for the first time, computer graphics tools to the general public. Now the types of tools being used to create graphics for the newspapers could also be purchased by the average computer user. New books became available to help guide scientists, engineers, and technicians in creating their own visualizations without the use of specially trained staff (Kosslyn, 1994; Tufte, 1990). In addition to general purpose graphing tools, off-the-shelf scientific visualization tools became more generally available, taking the place of custom-programmed tools that researchers were using to create more specialized visualizations.

The mid-1990s saw the greatly increased demand for 3-D modeling tools meet with affordable desktop computers capable of running this class of software. Now, both 2-D and 3-D graphics tools were available to the general public. During this time period, professionals in fields related to graphics also saw an increased demand for technological and computer competencies among both teachers and their students (Technology Assessment Project, 1999). This is coupled with an understanding of the important role that hands-on activities can play in the math, science, and technology classrooms (Luna, 1998).

Transformation to Scientific Visualization

In the 1990s technical and engineering graphics courses in secondary and post-secondary institutions across the country began facing criticism concerning their content. Even after the move to 2-D/3-D computer-aided drafting (CAD), many still questioned whether it was relevant to teach a highly specialized mechanical or architectural graphics language to a broad population of students (Raudebaugh, 1996). In this context, many professionals and researchers in graphics began to explore the role graphics played in a larger instructional and work context.

During the 1980s and 1990s, a resurgence of interest in the importance visualization plays in success (both in the classroom and in professional life) emerged. Several researchers recognized that the creation and manipulation of both traditional and computer-generated graphics can improve visual communications in engineering-related professions (e.g., Bertoline & Miller, 1989; Rodriguez, 1992; Sorby & Baartmans, 1994; Zsombor-Murray, 1990). Though many in the technical graphics field who teach at secondary and post-secondary educational institutions have discussed the benefits of traditional technical graphics as a means of developing spatial visualization skills, this was still envisioned by most as happening in the context of mechanical or architectural design graphics. During this time period, however, science educators also recognized the importance of enhancing the visualization abilities of students and professionals (Baker & Pilburn, 1997). Science educators were, as it can be imagined, using very different examples to show the use of graphics than would typically be seen in a mechanical engineering graphics classroom.

In the early 1990s we began to study how some hands-on activities used in engineering graphics classes could be used with a broader population of science and technical majors (Wiebe, 1992). In this scientific visualization course, rather than using the documentation of mechanical objects as the vehicle for the creation of graphics, the communication of more conceptual scientific and technical ideas and empirical results were used as a basis for creating graphics. We felt graphics communication principles formalized by theorists in the 1970s and 1980s and applied in professional science and technical professions could also be applied in technical graphics courses at the secondary and post-secondary levels (Bertoline, Wiebe, Miller & Mohler, 1997). This goal, facilitated by the increasing affordability of 2-D and 3-D computer graphic tools and the recognized need to address the graphic/visualization literacy issue at earlier grades, led to the expansion of this effort to secondary schools (Clark, Wiebe & Shown, 1996; Wiebe & Clark; 1998 North Carolina Public Schools, 1997). Though many look to our field as a source of applied skills for professionals in the science, technology, and engineering fields, there was the realization that many of the traditional concepts of technical graphics communication could be applied in a different context to a broader field of scientific visualization.

Scientific and Technical Visualization Curriculum

Unlike the architectural and mechanical tracks, scientific visualization courses are unlikely to prepare students for a vocation directly out of high school. Instead, these courses prepare students for a community college program related to scientific visualization or for enrichment in a scientific or technical career in engineering, technology, education, or the physical sciences. Therefore, potential students are likely to be those on an academic track who have never taken a vocational course before.

The scientific visualization courses expose students to all of the major conceptual areas associated with scientific visualization and give them experience in a broad range of graphic techniques. Unlike many of the graphic techniques covered in the architectural and mechanical areas, scientific visualization techniques are more broadly applicable. Also, because the track is more academic, students focus on theory and operations so they understand why particular graphic techniques are used. The primary areas covered in scientific visualization courses include:

- Basic design principles
- Graphing/plotting
- Image processing
- 2-D/3-D modeling
- Animation and simulation
- Presentation and publication

The curriculum team, consisting of teachers and administrators from both secondary and post-secondary education, decided to have five major competencies for the first-year curriculum (Table 1). The first competency centers on leadership development. This competency is designed to give students basic leadership skills and to develop a career plan that will include the information taught within this curriculum. The second major competency teaches students problem solving using design concepts involving visual science theory. Total Quality Management (TQM) tools are included to aid the students in finding solutions to problems and to develop consensus-building measures for working in groups. While students are working on problem-solving and critical-thinking skills, the third competency teaches students how to use computers as tools for visualizing scientific data and information. The fourth and fifth competencies are the most demanding. These competencies require students to use a computer to learn different visualization principles needed to analyze information and apply knowledge toward a scientific problem. Eighty percent of the course is conducted around these two competencies. Major focus areas for competencies four and five include the following: coordinate systems, spatial relationships, time representation, geometric shapes, terminology, orthographic projection, pictorial projection, shape properties, color, qualitative and quantitative data, dependent and independent variables, scales, and technical presentation skills.

In the second year, the curriculum centers on 3-D graphics and image processing (Table 2). With a focus on applications rather than cognitive knowledge-based learning, students incorporate advanced visualization techniques that are used to enhance existing models. These techniques include the use of advanced color and lighting. Also, students have a greater emphasis in conducting both quantitative and qualitative research. The main focus for this second-year curriculum is to develop and present a project in a portfolio format for assessment by the teacher and

Table 1. Scientific and Technical Visualization I Curriculum Outline.

1. Leadership Development:
   - Basic techniques for parliamentary procedure
   - Steps for processing a motion/vote
   - Establish goals
   - Identify of career goals
2. Apply Problem Solving and Design Concepts:
   - Explain the concepts and principles of problem solving and design
   - Apply problem solving and design methodology
3. Basic Computer Knowledge and Concepts:
   - Identify and explain basic computer terms and concepts
   - Provide advantages and disadvantages for using computers in scientific visualization
   - Apply concepts and principles of computer file management
4. Visualization Principles:
   - Identify and explain the application of description systems for space and time
   - Explain the fundamental concepts of shape description
   - Identify and explain visual properties of objects
   - Describe visual methods for representing data-driven visualizations

Table 2. Scientific and Technical Visualization II Curriculum Outline.

1. Advanced 2-D and 3-D Visualization Techniques:
   - Use color, texture, lighting, and rendering
   - Research based graphing for both quantitative and qualitative data
   - Image processing, simulation, and animation
2. Presentation techniques
   - Use software to present scientific and technical data
   - Develop interactive presentations with story boards
   - Present research data and develop a portfolio

classmates. The end result is that students understand and apply their visualization skills in scientific-related fields. Thus, upon completion of both classes, students may want to pursue a career using these skills in a science-related profession or relate these visual skills to other professions while enhancing their capabilities at using graphics as a career-related function (Table 2).

Impact on Future Curriculum Development

A curriculum of this type influences the types of students who take a graphics class at the secondary level as well as the visualization skills of students. With a scientific visualization curriculum, secondary and post-secondary education technical graphics teachers will have students who want to understand visual science theories and apply these visual techniques to more than just mechanical or architectural areas. Thus, the new scientific visualization curriculum will bring a new type of student to the classroom: those who want to apply visual techniques into academic areas such as mathematics, science, technology, chemistry, physics, and biology. This new curriculum allows these “nontraditional” students to see how visual science can be applied to other careers.

Scientific visualization allows students to create the graphics they would normally see in television science specials or in their textbooks. In addition, students have the opportunity to delve into science and technology topics at a depth not allowed in a traditional science class. They do this within the framework of a formal graphics communication discipline (previously outlined). There is the additional benefit that the vehicle of creating scientific visualizations also emphasizes key computer skills for the 21st century: data format standards and data exchange techniques, Internet-based data harvesting and research, 3-D modeling and animation, image processing, data input and output using numerous multimedia formats, and learning computer graphics hardware standards.

Although this new curriculum is developed as a vocational track, the concepts and information used throughout the curriculum can easily be integrated into mathematics, science, and technology education classes. Technology education teachers can use the curriculum structure, as well as its data or conceptual-based problems, to teach students ways to manipulate technical, mathematical, and science data and visually see the results. Therefore, technology education teachers can help students to develop visualization skills through classroom instruction and laboratory-based problems, and integrate technology in other scientific areas.

Application of Scientific Visualization

Scientific visualization is first placed in context with other technical graphic communication methods. The exploration of systems is introduced along with a review of the general types of systems that might be explored, analyzed, and presented using scientific visualization techniques. A foundation is built around understanding the different types of data variables, which may be used to describe both the probing and recording techniques used on the system.

In creating a visualization, the initial design is typically driven by classifying graphics into two major categories. First, one must determine if the visualization is concept-driven or data-driven. A concept-driven visualization is typically generated from a concept or theory and not directly tied to any empirical data. It does not mean that there isn't any data that either supports or refutes the theory, but this particular exploration does not require one. For example, if the goal is to represent the development of a volcano over time or the effects of harmonics in a suspension system on a car, it may be more effective to use diagrammatic techniques to represent the phenomena rather than to graph data values. A data-driven visualization uses empirically or mathematically derived data values to formulate the visualization. In this case, a specific relationship between data values and the graphic elements is defined so that a graphic characteristic varies in some predetermined fashion.

The second category is whether the visualization is to be represented in two or three dimensions. Evaluation of both the information to be presented and the capabilities of the computer hardware and software being employed also become factors in deciding on the dimensionality of the visualization. Since both concept-driven and data-driven visualizations can be represented in either two or three dimensions, a matrix of four possible visualization types is derived. The four visualization types are 2-D concept-driven, 3-D concept-driven, 2-D data-driven, and 3-D data-driven. This matrix can be used as means of classifying assignments and examples in the scientific visualization course. These visualization types are explored, analyzed, and presented through multiple techniques that are used extensively in graphic communications. In order to support the curriculum, examples of activities using these different visualization techniques were developed and placed on a web site and CD-ROM for use by teachers (Wiebe & Clark, 1997). Below are the major categories that many of the activities fall into, along with some examples.

Graphing/Plotting

A taxonomy is presented to students that classifies visualization methods used, based on both the types of data variables used and the intended audience. In addition, the basic graphic elements in graph plotting are introduced along with a review of two-dimensional coordinate systems used for organizing the graphic elements. Graphing and plotting exercises are done based on a number of different application areas. In some cases, the data can be collected from experiments the students create. In other cases, the data may be gathered from both print and electronic (e.g., Internet) sources. The primary focus in this section is 2-D graphing/plotting methods, manually done and using computer-based tools (Wiebe, 1997a).

Weather Data Exercise

The federal government's National Oceanic and Atmospheric Administration (NOAA) is a rich source of both historic and current weather data from around the country. NOAA's National Climatic Data Center's (NCDC) web site contains access to local climatic data collected on an hourly basis at airports and other key weather stations (NCDC, 1999). In this example, weather data were gathered from the Raleigh-Durham International Airport in North Carolina (Station: RDU, WBAN: 13722, Latitude: 35°52') and a station on the Ponape Caroline Island, Micronesia (Station: PTPN, WBAN: 40504, Latitude 6°58'). Presented in spreadsheet form, data such as the minimum, maximum, and average daily temperatures can be compared month to month, year to year, and from station to station. The graph in Figure 1 compares the minimum/maximum daily temperatures for December of 1996 and 1997 at RDU. In addition to looking at the variation at a single weather station, comparisons can also be made across stations. Figure 2 shows the differences in minimum/maximum daily temperatures for December of 1997 for both the North Carolina and Micronesia stations. Besides an overall warmer temperature, there is also less spread between the minimum and maximum temperatures in a day or week. Is this due to its closer proximity to the equator, proximity to a large body of water, or other factors? Graphical comparisons can be made with other weather stations around the globe using a number of different graphing techniques to explore these questions. These graphs become vehicles both for making sense of numeric weather data and for challenging the student to come up with effective visualization methods integrating multivariate data.

Image Processing

This part of the curriculum focuses on area rendering techniques using image-processing techniques. Also included is an introduction to color theory-both its perceptual basis and computer-based generation methods. Through the use of image processing software, the basic principles of how such software is designed and functions is explored. Image processing exercises are based on data gathered from

Figure 1. Minimum/maximum daily temperatures for December of 1996 & 1997

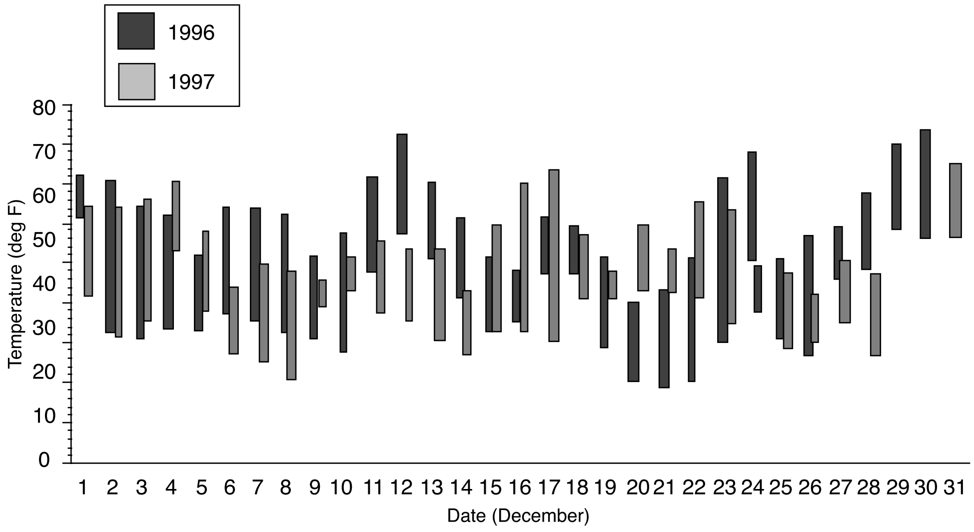
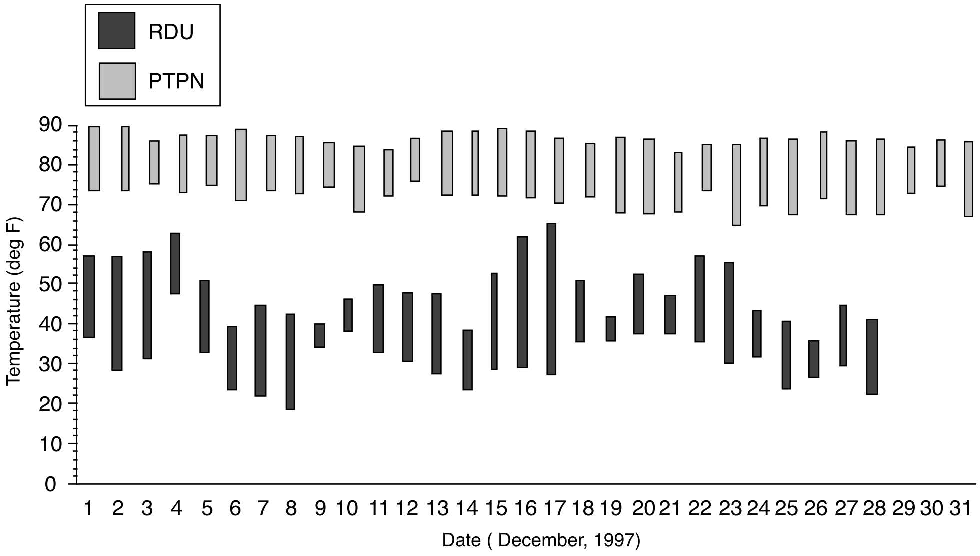


Figure 2. December 1997 temperatures compared across two weather stations at markedly different locations on the globe.



both images created by the students (either using all digital or a combination of photographic and digital methods) and images acquired through the Internet. Throughout this section, techniques used by professions that rely on image-processing techniques (i.e., medical and earth sciences) are examined (Wiebe, 1997c).

MRI Scan Problem

With this problem, students are given a series of magnetic resonance imaging scans of a human head. Within these images, a large cavity is identified where cerebrospinal fluid flows through ventricles. This region is highlighted by selecting and manipulating the pixel values of this region in each of the slices using image-processing techniques. When the region is highlighted in all of the appropriate sections, this region in each of the slices is recompiled and an animation created of the region being rotated. This exercise not only allows students to explore image-processing techniques and learn about human anatomy, but also lets them apply sectioning and projection techniques in ways not available in a traditional technical graphics class.

Animation, Modeling, and Simulation

Two major new areas are introduced in this area: dynamic visualization and 3-D modeling techniques. Dynamic visualization through animation and simulation shows how the change in a system over time either predefined or as a real-time response to user input can be represented. Two-dimensional simulation is explored using software tools modeling either physical (e.g., dynamic mechanism motion) or conceptual (e.g., model of a virus) systems. Similarly, 3-D modeling tools can be used to create representations of systems, which can then be manipulated to represent some process. The 3-D model can be the basis of a static image or used for animations to represent a dynamic process. Coupled with the creation of 3-D models is an introduction to rendering techniques, including proper use of lighting, color, and camera position (Wiebe, 1997b).

Newtonian Physics Problem

Though many areas of physics lend themselves to visualization, Newtonian physics stands out as an excellent example of how 3-D and 2-D visualizations can help support learning about physical principles. Formulas representing the principles of Newtonian mechanics often use spatial coordinate values both as independent and dependent variables. These values cannot only be represented in traditional graphs, but also as symbolic models. In this sample problem, students take theoretically derived data to create an animation of a cannonball-given an initial velocity and vector-being shot from a cannon and model it in a 3-D modeling and animation package (see Figure 5). This exercise represents a blend of concept-driven and data-driven visualization. Besides creating a pictorial view of the ball trajectory, animations from orthographic viewpoints (i.e., top, front, side) of the trajectory can be created to isolate movement along pairs of coordinate axes. This allows students to visually identify along which axes acceleration is taking place.

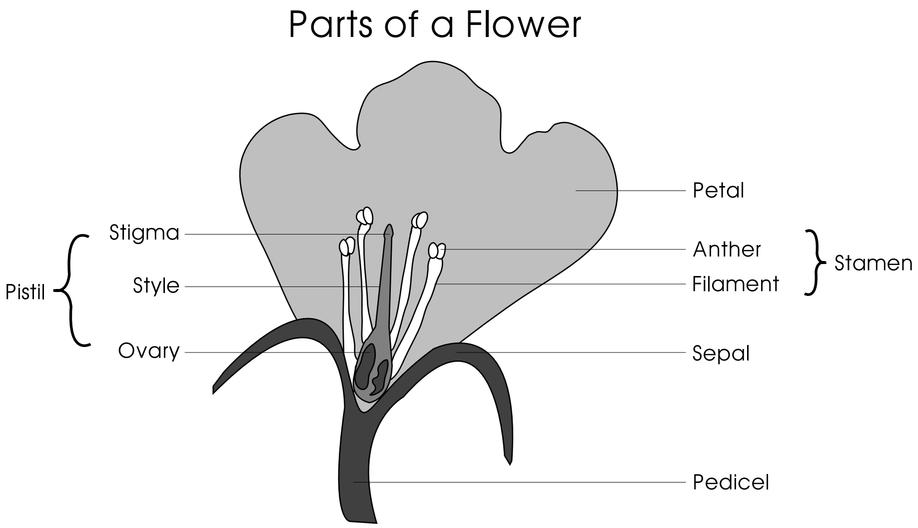
Presentation and Publication

This last area focuses on the integration of information used to represent and analyze a system into a form that can be presented to an audience. Information sources include textual and numeric data in addition to the graphics created as part of the visualization. The focus is on the clear and concise presentation of necessary information to the intended audience. Exercises use multimedia presentation software that integrates text with both static and dynamic graphics (see Figure 3). This last area can be used as part of a capstone project encompassing both the scientific visualization course and other related courses. The presentation process emphasizes the use of multimedia formats being integrated into a project that extends from a comprehensive study about a given scientific subject.

Vocational and Technology Education's Role Within Scientific Visualization

Vocational and technology education within North Carolina and across the nation has many things to consider during the development and implementation of this new curriculum. First, scientific visualization is not limited to vocational students, and all students in engineering, scientific, and technological areas can use visualization techniques. Therefore, technical graphics programs should include scientific visualization and teach students how visualization skills can be used outside of traditional engineering fields. Since one of our goals in vocational and technology education is to integrate our curriculum content with general education in order to establish technological literacy, scientific

Figure 3. An illustration of a flower integrated with text labels.



visualization will broaden our technical graphics curriculum and prepare students to integrate visualization skills in other professions (e.g., chemistry, medicine, biology, physics, meteorology, agriculture).

Second, vocational and technology educators need to consider the demand for a technical graphics teacher to teach this type of curriculum and team teach with other educators from other disciplines. Science teachers know the content, but vocational and technology teachers know the processes for visualization. Scientific visualization with its content and visual processes requires integrating both the academic and vocational areas. Thus, technical graphics teachers need training in this new integrated approach to teaching. They will also need updated skills to include new software and scientific content that are directly related to the curriculum.

Finally, teachers of technical graphics in two and four-year programs need to include this new content into the existing curricula of any type of graphic communications program. It is expected that the graduate understands the many forms and processes where visualization is being used. It is the role of the college and university graphics educators to include this new content area and better prepare their graduates for employment, not only in the traditional technical graphics area, but for the emerging areas within scientific visualization. Our responsibility as vocational, technical, and technology educators at the post-secondary level in graphic communications is to educate our students in the skills and knowledge needed for the 21st century.

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Scientific Visualization 1

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Appropriate Technology for Socioeconomic Development in Third World Countries

Anthony Akubue

Introduction

Persistent socioeconomic problems in Third World countries, despite decades of massive infusion of advanced technology from the industrial world, continue to elicit questions regarding the appropriateness of this technology in the Third World. The concentration of wealth in the hands of the Third World ruling class, bureaucrats, and the elite-the hallmark of a growth-based development strategy-makes life a continuous struggle for a great mass of the people. Problems of poverty, unemployment, inequality, and basic needs fulfillment are common facts of life today in many Third World countries. Worsening socioeconomic conditions in the Third World have underscored the urgency of implementing a development path that de-emphasizes growth and technological monoculture. The technological orientation of this development paradigm has been variously called intermediate, progressive, alternative, light-capital, labor-intensive, indigenous, appropriate, low-cost, community, soft, radical, liberatory, and convivial technology. However, appropriate technology, for reasons to be addressed later, has emerged as the all-embracing rubric representing the viewpoints associated with all the other terms.

The purpose of this article is to discuss appropriate technology as it concerns social and economic development in the Third World. Detractors and advocates of appropriate technology have made claims and counter claims about its strengths and weaknesses. Not surprisingly, some of these claims are often imbued with prejudice, ignorance, or intolerance (Jequier, 1976, Kaplinsky, 1990; Willoughby, 1990). The view espoused in this article is that the national and intranational disparities in the level of development of the Third World are so great that any suggestion of inflexibility in the technological and socioeconomic development strategy employed would be grossly unrealistic. Third World development must not take an either/or stance regarding technology input; it requires both large- and small-scale appropriate technology.

Some Compelling Issues

The conventional development strategy for the Third World is and has been dominated by economic growth. In the process of its implementation, industrialization became equated with development. To this end, industrialization by way of capital accumulation and technology transfer from the industrial nations to the Third World were pursued with immense interest. Decades of massive importation of advanced technology and the implementation of large-scale, capital-intensive production methods in Third World countries have revealed the shortcomings of such an approach. First of all, the strategy entails the employment of capital-intensive technology in countries that are short of capital and endowed with surplus labor. Third World countries, by opting for capital-intensive production technology in spite of their shortage of capital, can only afford to create a few jobs for a small number of people due to a very high capital/labor ratio. This implies that several Third World countries equip only a very small proportion of their labor force with the means of increasing production. In this case, small islands of high productivity emerge in core urban centers at the expense or neglect of the periphery involving the more populous segment of the economy. The result has been the creation of a dual economic structure (consisting of a prosperous modern sector and an impoverished traditional sector), worsening unemployment conditions, and widespread abject poverty in many Third World countries. According to a 1976

U.S. Agency for International Development (USAID) proposal to the U.S. Congress, the effects of capital-intensive technology are not limited to problems of unemployment in the Third World. "The high capital cost of modern technology has also contributed to the development of dual economies-small, relatively well-off enclaves of high productivity and well-paid workers side by side with relative stagnation among the larger community" (Thormann, 1979, p. 282). There are writers who attribute growing poverty in the Third World in part to rapid growth in the modern sector that is sustained with the most advanced imported technology (Singer, 1985). This growth in Third World metropolitan areas is often accompanied with little or no spread effect to the sectors in the periphery. Commenting on this issue, Robinson (1979) observed that "a growth strategy that takes the form of industry-led development, using the technologies that are appropriate for Western societies, leaves almost untouched in the rural areas increasing absolute numbers of impoverished and underemployed workers" (p. xii). It is because this growth has failed to create sufficient employment opportunities and the growing disparity in progress between regions that concerns have been raised about the conventional development strategy. The World Bank even touched on the inevitability of getting priorities right in terms of the pattern of development that best addresses the needs of the Third World:

> The choice to be faced ... is whether to invest heavily in a few workers and in services for a few to increase their production and living standards substantially, leaving the rest unaffected by growth (or at best affected indirectly), or whether to make some gain in the productivity of many people by investments at lower per capita affecting the mass of the people in the country.
>
> (Willoughby, 1990, p. 118)

As mentioned earlier, an impact of the pattern of growth in metropolitan areas of the Third World is the development of a dual economy. This has been blamed for causing, among other things, a constant influx of people into the cities from the rural sector. Not only is this rural-urban migration a threat to the economy of the rural sector, but also to the survival of the modern sector as it struggles to cope with an exploding urban population. The modern sector is the creation of mostly advanced, capital-intensive technology imported from the rich industrialized countries. Schumacher (1973) blamed this technology for creating what he called the "process of mutual poisoning" in most of the Third World. This is a condition in which the concentration of industrial development in Third World cities adversely affects the economy of the traditional sector as people abandon their traditional undertakings to move to the cities. This movement in turn affects the cities adversely by overpopulating them and causing problems almost impossible to manage. The relationship in this case becomes one of mutual destruction. This manifests itself today in the Third World in the form of high rates of unemployment, poverty, great income disparity, and declining access to basic needs. This being the case, a major challenge today in the Third World is to articulate an effective approach to ensure that benefits from development are within people's reach regardless of where they live.

Appropriate technology as a development approach is intended to address such socioeconomic problems, especially in the rural and informal sectors. Stewart (1985) perhaps put the need for appropriate technology in perspective in the following statement:

> The argument for appropriate technology is not that jobs should be put before output, but that techniques can be developed which promote both. Appropriate technology is intended to raise productivity and incomes outside the advanced technology sector and so extend the benefits of development throughout the population. (p. 28)

It goes without saying that using appropriate technology to stimulate production and employment in the sectors outside the modern sector is such an important objective that it ought to be seen as a national imperative. It is unreasonable not to promote appropriate technology for development in the traditional and informal sectors in view of the capital and foreign exchange situation in many Third World societies. Development in these regions must start with less complex and expensive techniques and move forward.

Development Path

Communities, societies, or countries have evolved historically with the type of technology that reflects their level of development and factor endowment. For example, the capital stock of the United States late in the 18th century consisted of hand pumps, Franklin stoves, wooden plows, and draft animals (Norwine & Gonzalez, 1988). During the reign of Mao Tse-tung, communist China turned to appropriate technology for rural development after a major disagreement led to a break up with Russia in 1960. In the succeeding period of Cultural Revolution, China's policies on development centered on the phrase "walking on two legs". This entailed the encouragement of technological dualism for the simultaneous development of large-scale and small-scale undertakings to promote industrialization nationwide in China (Pacey, 1990; Riskin, 1979). While concentration in the urban areas was on building large-scale, capital-intensive factories, the focus in the rural areas was on the development of small-scale industries based on appropriate technology. According to Perkins (1980), "rural small-scale industrialization depended in a fundamental way on the prior and continuing successful development of urban large-scale industry" (p. 187). The rural industries, making use of intermediate technology, were expected to take advantage of the country's abundant local resources, including industrial waste or scrap from the large-scale, city-based factories (Riskin, 1979). But the uniqueness of this new direction was that it emphasized the decentralization of production, the reliance on domestic initiatives, and the pursuit of self-sufficiency. Writers such as Dwight H. Perkins have argued that China's encouragement of small-scale industries making use of appropriate technology in the rural areas created jobs and enabled China "to avoid some of the worst aspects of the urban-rural polarization that characterizes so many developing countries" (Long, 1980, p. 7).

However, before China's "walking on two legs" and "relying on its own forces" (Dunn, 1978, Jequier, 1976) initiative, the concept of appropriate technology had long been an important part of India's village industries even before the 1930s. One of India's early pioneers and practitioners of appropriate technology was its moral leader and advocate of nonviolent resistance Mohandas Karamchand Gandhi. Gandhi's familiarity with the work of Henry David Thoreau of the United Sates exerted great influence in shaping his philosophy of development. In fact, a number of writers on appropriate technology have variously referred to Gandhi as the "father" of appropriate technology and the "first appropriate technologist" (Betz, McGowan, & Wigand, 1984; Rybczynski, 1980), knowing full well that the phrase gained common usage only after Gandhi's time. As Rybczynski (1980) pointed out, "it was Gandhi who, before China's Mao Tse-tung, recognized that the peasants should be the basis for economic development in Asia" (p. 37). Gandhi spoke incessantly of the need for village industries in India, while maintaining that India's survival and future were dependent on the state of the villages where most Indians reside. Underlying Gandhi's notion of village industries was his epigrammatic expression that "the poor of the world cannot be helped by mass production, [but] only production by the masses" (Schumacher, 1973, p. 153). From Gandhi's perspective, any concern with goods requires mass production, but concern with people necessitates production by the masses.

The Charkha (spinning wheel) was Gandhi's ideal appropriate technology device, and he saw in it a symbol of freedom, self-reliance, and a technical means that was right for India. The idea of technology discriminately enriching a minority of people at the expense of the majority or putting masses of people out of work to increase profit was in Gandhi's view counterproductive and unacceptable. However, Gandhi was not uncompromising in his rejection of large-scale, capital-intensive industrial enterprises. Modern-sector industrial development, in Gandhi's view, should supplement and reinforce the development of small-scale industries and agriculture in the hinterland. In a quote credited to Gandhi, he expressed his choice of the development path suited to the Indian sub-continent:

> If I can convert the country to my point of view, the social order of the future will be based predominantly on the Charkha and all it implies. It will include everything that promotes the well-being of the villagers. I do visualize electricity, ship-building, ironworks, machine-making and the like existing side by side with village handicrafts. But the order of dependence will be reversed. Hitherto, the industrialization has been so planned as to destroy the villages and the village crafts. In the State of the future it will subserve the villages and their crafts... (Bhatt, 1980, p. 172)

In his effort to start India in this development path, Gandhi founded organizations such as the All India Spinners Association and the All India Village Industries Association' (Dunn, 1978). A group known as Gandhian economists later founded the Appropriate Technology Association of India, one of the early appropriate technology organizations. Prominent among the non-Indians who shared Gandhi's philosophy was Dr. Ernst Friedrich "Fritz" Schumacher, who later played a key role in popularizing appropriate technology worldwide.

From Gandhi to Schumacher

Before becoming a respected leader in the appropriate technology movement, Schumacher was a well-established economist. In fact, Schumacher's work as a top professional economist is believed to have influenced great economists such as John Maynard Keynes. According to Willoughby (1990), Keynes' wish before his death was for his mantle to fall on either of two people– Otto Clarke or Fritz Schumacher: "Otto Clarke can do anything with figures, but Schumacher can make them sing" (p. 57). Both Clarke and Schumacher worked with Keynes for the British Treasury. Later experience convinced Schumacher to become an ardent advocate of a different technological and socioeconomic development path.

Born in Bonn, West Germany, in 1911, Schumacher moved to England in the late 1930s. As a German immigrant in Britain, he endured a period of trial and tribulation during World War II. In the end, Schumacher distinguished himself as a great economist and worked in different capacities for various British establishments, including the position he held for more than 20 years as senior economist and economic advisor to the British National Coal Board (NCB) (Kaplinsky, 1990, Schumacher, 1974; Willoughby, 1990). His experience as an employee of the NCB persuaded Schumacher to reconsider his support of large-scale organizations.

> Schumacher was first sensitized to the problems of scale by the NCB's attitude to the problems of pneumoconiosis [black lung disease], a lethal disease of the lungs associated with coal-mining. Instead of recognizing the self-evident health consequences of coal-mining, the NCB chose to defend itself rigorously and to fight (and subsequently win) the legal argument on technicalities. In saving itself relatively small sums of compensation (2–3 million Pound Sterling), Schumacher believed that the NCB had ceased to concern itself with people. More importantly, he believed that such uncaring attitudes were not exceptional but were an inevitable consequence of the organization's scale. (Kaplinsky, 1990, p. 137)

Schumacher's new philosophy was further shaped from a 1955 trip to Burma, where he served under the auspices of the United Nations as economic adviser to U Nu, the country's prime minister at the time (Crittenden, 1975; Rybczynski, 1980; Schumacher, 1974; Willoughby, 1990). While in Burma he encountered an economic setting quite unlike what he was used to in Germany, Britain, and the United States. With very low income per capita in Burma, which would be tantamount to poverty from a Western view, Schumacher was amazed that the Burmese went about their daily lives apparently quite happy and content. Living in Burma also revealed to him some of the inadequacies of a growth-based conventional development strategy. Such a strategy encouraging the use of capital-intensive technology from the industrialized societies was having some harmful consequences in Burma and other Third World countries. These observations, among others, led Schumacher to the conclusion that the "problems of economics do not have any final solution, because they are human problems, that can be 'solved' only within a particular set of circumstances for a particular time and particular place" (Cornish, 1974, pp. 276-277). Living in Burma also brought Schumacher in contact with Buddhist economics, one of the most influential forces behind his thinking and ideas.

Another major event that occurred while Schumacher was in Burma was his discovery of Gandhi, a man he later called the greatest economist of the 20th century (Crittenden, 1975). According to Crittenden (1975), Schumacher was a self-proclaimed "indiscriminate thief of ideas," who credited much of his ideas about development and preservation of the natural environment to Jesus, the Buddha, and Gandhi. In subsequent years, through contacts and familiarity with Gandhi's work, Schumacher developed the ideas and reputation that earned him an invitation to Hyderabad, India, in the early 1960s. While in India at the invitation of the Indian Planning Commission and his friend Jayaprakash J. Narayan, he gave a seminar on Technologies for Small Industries in Rural Areas (Dunn, 1978). His visit to India was a welcomed opportunity for Schumacher, for he was able to study Gandhi's approach at close range and meet with acclaimed Gandhian economists.

The Birth of Intermediate Technology

Motivated by disillusionment with large-scale organizations and his experience in Burma and India, Schumacher developed the ideas behind the concept of intermediate technology, which became the linchpin of his seminal book *Small Is Beautiful: Economics*

As If People Mattered, published in 1973. Perhaps, more than the others, Gandhi's work exerted the most influence on Schumacher. In using the term intermediate technology, Schumacher envisioned a technology for the Third World that was midway between, for example, a hand hoe and a tractor. As Schumacher (1973) described it, "Such an intermediate technology would be immensely more productive than the indigenous technology...but it would be immensely cheaper than the sophisticated, highly capital-intensive technology of modern industry" (p. 180). In order for the concept of intermediate technology to be considered useful, it must be conducive to meeting the challenges outlined in the following propositions:

- Workplaces have to be created in the areas where the people are living now, and not primarily in metropolitan areas into which they tend to migrate;
- These workplaces must be, on average, cheap enough so that they can be created in large numbers without this calling for an unattainable level of capital formation and imports;
- The production methods employed must be relatively simple, so that the demands for high skills are minimized, not only in the production process itself but also in matters of organization, raw material supply, financing, marketing, and so forth;
- Production should be mainly from local materials and mainly for local use. (Schumacher, 1973, pp. 175-176.)

To tackle these challenges, Schumacher and his colleagues founded the Intermediate Technology Development Group (ITDG) in London in 1965 (Schumacher, 1974). Since its inception, the ITDG has been providing information on existing low-cost, labor-intensive technologies, creating nonexistent technological innovations, and publishing important how-to-do manuals on affordable do-it-yourself work methods. The organization has also been responsible for convening major conferences on simple, low-cost technologies for small-scale industries. For example, in 1968 a trail-blazing conference convened at Oxford University. The aim of this conference was to promote intermediate technology for Third World development and enlist industrial involvement in its development (Rybczynski, 1980). As it happened, one of the issues raised at the conference was the necessity of a name change. Intermediate technology was viewed to be suggestive of a technology that was inferior or second-rate (Kaplinsky, 1990; Willoughby, 1990) and conveyed only the economic and engineering aspects of innovation. The term was further "criticized for implying a technological fix for development problems, separate from the social and political factors involved" (Hollick, 1982, p. 214). The phrase appropriate technology was suggested as a substitute, in part for including the social and cultural dimensions of innovation (Pellegrini, 1979), and, unlike intermediate technology, for not evoking the specter of inferiority. The rationale was that with appropriate technology the chances of its acceptance by those for whom it was intended would be greatly improved. Although intermediate technology is still used, appropriate technology has become the popular and more widely used appellation. The world owes the appropriate technology movement to Gandhi and Schumacher, who are widely acknowledged as its progenitors. Schumacher's role in turning appropriate technology into a household phrase cannot go unacknowledged. So outstanding was this contribution by a single individual that Rybczynski (1980) even opined that "E. F. Schumacher was undoubtedly the motive force behind the appropriate technology movement. It is not an exaggeration to say that without him there would have been no appropriate technology" (p. 6). Individual feelings apart, Schumacher, through his passion and dedication to the cause, established himself as a leading authority on appropriate technology.

What Is Appropriate Technology?

Appropriate technology may have been practiced for many generations in the past, but there is something new about it today; it has evolved into a development approach that is aimed at tackling community development problems. Viewed in this way, appropriate technology cannot be seen simply as some identifiable technical device; rather, it is an approach to community development consisting of a body of knowledge, techniques, and an underlying philosophy. In fact, Dunn (1978) called it a complete systems approach to development that is both self-adaptive and dynamic, because as its users become wealthier and more skilled, they can both afford and also use more expensive technical means. As Hazeltine and Bull (1999) noted, the experience of countries such as the United States "appears to confirm that one of the advantages of appropriate technology is that it can be an effective way to shift to modern technology" (p. 277). In this case, appropriate technology can only be considered transitional and not static. It follows, then, that as appropriate technology improves the productive capabilities of a community, the community influences and improves the level of technology as well. In this article, appropriate technology is defined as an approach to development that not only emphasizes job creation and optimum use of existing skills and resources, it also builds on the skills and resources to raise the productive capacity of a community. Other definitions by different writers have contributed significantly to a better understanding of appropriate technology.

Other Definitions of Appropriate Technology

The proposal mentioned earlier for the development and dissemination of appropriate technology in the Third World was prepared and submitted to special U.S. Congressional Committees by the USAID in June1976. This proposal featured the following description of appropriate technology.

> In terms of available resources, appropriate technologies are intensive in the use of the abundant factors, labor, economical in the use of scarce fac tors, capital and highly trained personnel, and intensive in the use of domestically produced inputs. In terms of small production units, appropriate technologies are small-scale but efficient, replicable in numerous units, readily operated, maintained and repaired, low-cost and accessible to low-income persons. In terms of the people who use or benefit from them, appropriate technologies seek to be compatible with local cultural and social environments. (Thormann, 1979, 283-284)

Another interesting and enlightening description of appropriate technology is one by Bourrieres (1979), who presented this as:

> one which uses the largest number of people as they are, with the training they have had and with their actual technical and financial aspirations. But while technology must correspond as closely as possible to actual manpower supply, teaching and training methods should endeavor to improve that supply so as to meet the requirements of the most productive technologies. (p. 5)

Pellegrini (1979) suggested that a technology should be considered appropriate "when its introduction into a community creates a self-reinforcing process internal to the same community, which supports the growth of the local activities and the development of indigenous capabilities as decided by the community itself" (p. 2).

Harrison (1980), a freelance journalist specializing in Third World development issues, stated that

> appropriate technology means simply any technology that makes the most economical use of a country's natural resources and its relative proportions of capital, labor and skills, and that furthers national and social goals. Fostering AT means consciously encouraging the right choice of technology, not simply letting businessmen make the decision for you. (p. 140)

Todaro (1997), an economist, defined appropriate technology as:

> technology that is appropriate for existing factor endowments. For example, a technology employing a higher proportion of labor relative to other factors in a labor-abundant economy is usually more appropriate than one that uses smaller labor proportions relative to other factors. (p. 667)

Writing in the *Economic Journal*, Morawetz (1974) defined appropriate technology as the "set of techniques which makes optimum use of available resources in a given environment. For each process and project, it is the technology which maximizes social welfare if factors and products are shadow priced" (p. 517).

> In the definition by Betz *et al.* (1984), appropriate technology equated with providing technical solutions that are appropriate to the economic structure of those influenced: to their ability to finance the activity, to their ability to operate and maintain the facility, to the environmental conditions involved, and to the management capabilities of the population. (p. 3)

Other definitions list specific characteristics of appropriate technology. Take the definition by Jequier and Blanc (1983) for example:

> Appropriate technology (AT) is now recognized as the generic term for a wide range of technologies characterized by any one or several of the following characteristics: low investment cost per workplace, low capital investment per unit of output, organizational simplicity, high adaptability to a peculiar social and cultural environment, sparing use of natural resources, low cost of final product or high potential for employment. (p. 10)

Characteristics of Appropriate Technology

The last definition not only suggests the criteria for technological appropriateness, it also implies that there is such a thing as inappropriate technology. Such characteristics have been well documented by various writers and appropriate technologists (Carley & Christie, 1993; Congdon, 1977; Darrow and Saxenian, 1986; Dunn, 1978; Evans and Alder, 1979; Hazeltine & Bull, 1999; Jequier & Blanc, 1983; Schumacher, 1973;), and as a result will not be treated in depth here. The appropriateness of technology is not limited only to job creation, using local resources, and utilizing renewable energy resources but it is also about being affordable, easy to maintain, compatible with existing infrastructure, efficient in the use of scarce natural resources, environmentally benign, and partial to small-scale.

To many people, appropriate technology is always small, simple, cheap, and labor-intensive. Perhaps Schumacher, more than anybody else, contributed to that general perception. However, Anderson (1985) made the point that “scale, complexity and expense are not always positively correlated. It is possible for a large machine to be both simple and cheap and for a small one to be highly complex and expensive” (p. 68). It is not generally acknowledged that Schumacher expressed a similar idea about the issue of scale. For example, Schumacher stated: “Whether a given industrial activity is appropriate to the conditions of a developing district does not directly depend on ‘scale,’ but on the technology employed” (p. 179). It is conceivable that Schumacher’s commitment to smallness of scale was provisional rather than absolute, and may have had more to do perhaps with the prevailing idolatry of bigness still evident in today’s technological society than anything else. “Schumacher once told friends that, had he lived in a world of small organizations, he would have written a book called Big Is Beautiful” (Toffler, 1980, p. 247).

Diversity in the Choice of Technology

The characteristics or criteria of appropriate technology discussed above are not meant to imply that there is a perfect technology or a panacea that can resolve all the socioeconomic problems of the Third World at once. The fact remains that circumstances vary from one Third World society to another, and what is appropriate for one country or social setting may not necessarily be appropriate for the other. As Willoughby (1990) pointed out, “the concept of appropriate technology attempts to discriminate between different technologies according to their relative suitability for specific purposes or situations” (p. 6). Appropriate technology is not about taking a stand against technology, but about technology being a heterogeneous collection of social and technical options rather than a homogeneous phenomenon. From this collection, the best choices are then made based on the objectives to be accomplished and possible human and environmental effects.

The notion of appropriate technology suggests that all alternatives should be researched for “best fit.” The impression that advanced technology is invariably inappropriate for the Third World is an exaggerated and misleading interpretation of the intent of appropriate technology. It is not realistic to suggest that the development of the Third World should be based almost entirely on technological monoculture. One must keep in mind that the primary focus of appropriate technology is in rural and informal sectors of the Third World. This is in recognition that economic growth in the past several years has tended to be confined to the urban modern sector in part because of capital and foreign exchange shortage. Interestingly, campaigns against appropriate technology are usually spearheaded not by the poor who stand to benefit the most from its use, but by the rich and powerful elite group. The elite of the Third World are not the “poverty-stricken multitudes who lack any real basis of existence, whether in rural or in urban areas, who have neither the ‘best’ nor the ‘second best’ but go short of even the most essential means of subsistence” (Schumacher, 1973, p. 181). This is why the case has to be made for diversity in the pool of technology available for use in the Third World.

Since differences in the level of development and factor endowments do exist between and within countries, the notion that “one size fits all” definitely does not apply. Today’s intolerance of pluralism in global technological development is comparable to a situation once in the former Soviet Union about footwear production. According to Ernst F. Schumacher, “we have been like the Soviets who made 500 million pairs of shoes, all the same size, and said, ‘take it or leave it-this is the only way we know how to do it’” (as cited in Crittenden, 1975, p. F5). A technological diversity approach to Third World development can satisfy the needs of both the rich and poor of the Third World and promote participation for the poor in the development process. Brooks (1980) suggested along the same lines that "appropriate technology and current technology are complementary rather than mutually exclusive, and that the potential benefits of both will be enhanced when they coexist" (p. 54). From the foregoing discussion, it is clear that there is certainly an urgent need to expand the scope of technology and to integrate appropriate technology in the development of the Third World. However, appropriate technology has its critics.

Criticisms of Appropriate Technology

Appropriate technology has been the subject of numerous criticisms despite its obvious advantages. Common among the criticisms is the claim that appropriate technology is inefficient, a technology not congenial to growth and improving the standard of living. Often failed projects based on appropriate technology are cited as evidence in support of this criticism, as if any technology enjoys immunity from failure. Rybczynski (1980) cited cases of biogas digesters in India and South Korea that were abandoned either because they produced insufficient methane or for inadequate supply of cow dung as evidence of inefficient appropriate technology. This account only tells part of the story. A government National Project on Biogas Development in 1981 brought needed relief to many in rural India. For instance, biogas in Pura, a village in south India, has been meeting the water-pumping, electric-lighting, cooking, and fertilizer needs of this village's 485 inhabitants (Sampat, 1995). According to Sampat (1995), about 2 million biogas digesters have been installed in India since 1981, "and although the program has had its share of problems, it has made substantial progress" (p. 21).

Appropriate technology may not be efficient from an engineering standpoint, but it is pedantic and unrealistic to describe any technology that enhances the capacity to satisfy community goals and aspirations as inefficient. A related criticism claims that workplace productivity is compromised with appropriate technology. This argument implicitly suggests that output per worker is unimportant to appropriate technology. The fact is that appropriate technologists understand the important correlation between productivity and standard of living. On the other hand, it must be realized that given the endemic unemployment situation in most Third World societies the maximization of job opportunities is not a matter of subordinate priority either. It is possible that the effort to maximize productivity in the urban areas can be pursued simultaneously with the effort to maximize work opportunities for the unemployed and underemployed in the traditional and informal sectors. The issue is not about opting for either productivity or job creation, but, as mentioned earlier, finding a good mix of techniques to promote both and to ensure a far-reaching distribution of the benefits of development.

Furthermore, critics have made arguments of the kind that if appropriate technology is as effective as some of its advocates claim, it should have no difficulty displacing the dominant, capital-intensive technology. These critics advance the notion that the prevailing technology at any one time is the most efficient possible for that time (Brooks, 1980; Kaplinsky, 1990; Rosenbrock, 1979). This is probably one of those arguments based on the assumption of a "free market" and a qualifying ceteris paribus. It sounds quite presumptuous and too sanguine to completely rule out the possibility that the dominant technology may by chance not be the most efficient or effective. However, it is possible to sustain a wasteful technology through government intervention, institutional inertia, the actions of vested interest groups, years of enormous investment, and established position of the technology, all of which may be prejudicial to the development of alternatives. Given this possibility, Rosenbrock (1979) surmised that "it is quite conceivable that a worse solution could be perpetuated indefinitely this way" (p. 9).

One final criticism of appropriate technology is the claim that it is an inferior technology and a part of a scheme by Western industrialized countries to maintain their position of socioeconomic and technological dominance over the Third World (Kaplinsky, 1990; Thormann, 1980; Willoughby, 1990;). Whether this allegation is believable or not depends on one's perspective. Perhaps it is worth mentioning here that

> there is no evidence that a country which starts with simple technology cannot move into more complex technology, and there is much evidence that for countries starting with a simple technology the transition to industrialization was easier than it was for those that shifted directly to a complicated case. (Hazeltine & Bull, 1999, p. 277)

One must bear in mind that appropriate technology as defined by its proponents is a technology tailored to serve the particular needs of a given region or community. This implies that a painstaking effort is made to secure the "best" alternative there is for the set of circumstances peculiar to that region or community. So, "if one wished to have the best technology for given circumstances it would be absurd to advocate inferior technology and doubly absurd to call it 'appropriate', when, logically, it would not be the best available" (Willoughby, 1990, p. 237). As many commentators have already noted, many of these criticisms are not based on facts and often reflect the prejudices and biases of the critics. Willoughby (1990) put it more succinctly:

> Many criticisms of Appropriate Technology are based upon either ignorance of available empirical evidence, distortion of the claims of leading protagonists, or reliance upon examples from the literature which differ from the consensus of the movement but which suit the biases of the critic. (p. 234)

Concluding Remarks

There is a tendency to condemn appropriate technology for all the wrong reasons and regardless of its true intent and focus. Several writers have pointed out that many of the criticisms of appropriate technology have been made in spite of empirical evidence to the contrary (Kaplinsky, 1990; Willoughby, 1990). That said, it must be stated as well that there is also a tendency on the part of some appropriate technology advocates to overstate its role and effectiveness. Unfortunately, this stance sometimes underlies the attitude that appropriate technology is the only acceptable technological approach to Third World development. This seemingly intolerant attitude toward an integrated approach to development problems in the Third World only works to raise suspicion about the motives of some appropriate technologists. Jequier (1979) did put things in perspective years ago when he wrote:

> Appropriate technology is not, and should not be viewed as a second-best solution. Conversely, neither should its role be over-estimated: appropriate technology is not a universal substitute for the conventional modern technology.
>
> Appropriate and modern technologies are complementary rather than contradictory, and the emphasis given to the former does not and should not rule out the use of the latter in those cases where they are particularly well adapted to local conditions. (p.3)

However, it is interpreted that appropriate technology must be progressive and not retrogressive. Third World countries are advancing in socioeconomic and technological development and must move forward, not backward, with this progress. Appropriate technology is not meant to be static or promote stagnation but to change as a country achieves progress in its level of development. In the end a new and different kind of appropriate technology with emphasis on environmental sustainability must take precedence as success is realized in the eradication of abject poverty and the reduction of unemployment and inequality.

The need for labor-intensive technology in parts of the Third World in order to adapt to existing circumstances is understandable, especially in a situation of scarce capital. However, development must proceed beyond adaptation to concern itself with changing these circumstances. Desirable progress is desperately needed in the Third World and cannot be achieved merely by adapting to present conditions. The determinants of technological appropriateness must include an evolutionary capacity factor. In other words, it is essential "to bring innovators in appropriate technology to think not only in terms of today's needs and resources, but also in terms of building up a system of permanent innovation in appropriate technology" (Jequier, 1979, p. 20). A system of permanent innovation in appropriate technology in the long run should engender domestic capacity to absorb and generate needed capital and technology. Capital, internally or externally derived, is a necessary factor and must be an essential part of any formula for development in the Third World.

Finally, the establishment of several appropriate technology organizations in recent years is a necessary approach toward the adoption and diffusion of appropriate technology, but must not be the only strategy. A commonly cited obstacle to mass diffusion of appropriate technology is the existing power relations that favor advanced capital-intensive technology. Unless the current economic, political, and social structures that promote large-scale technology are overhauled to ensure a level playing field, the generation and diffusion of appropriate technology would remain suboptimal at best. This calls for some policy action to remove current incentives that are mostly in favor of capital-intensive technology. Dickson (1974) expressed the sentiments of many when he wrote that

> technological change must be viewed as a political process, reinforcing the interests of a dominant class. It also implies that development of non-alienating, non-exploitative technology requires more than just a nominal change in the ownership of the machines we now have. It includes a complete reshaping of our attitudes towards the function of technology in society-a simultaneous change, in other words, of both political and technological consciousness. (p. 95)

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What Happens to Industrial Technology Alumni? A Comparative Look at Two Universities' Graduates

William Brauer

My association with two industrial technology programs at two very different universities sparked my curiosity about their similarities and differences. This prompted a follow-up investigation to gather preliminary data about the graduates of programs that appeared to be similar at two institutions. The information gathered, along with my observations about both educational programs, permit me to briefly describe the similarities and differences of the curriculum at both institutions and their programs, as well as present job titles of their graduates and to offer suggestions about possible additional research and implications for the profession.

Nationally, the number of bachelor graduates in technology has increased in the past decade. This increase is reflected in the growth of the School of Technology at Purdue University. Since its beginning in 1964, the School of Technology has graduated over 18,000 students and has grown into a school composed of eight departments representing many different technologies (Lawshe, McNelly, and Gentry, 1990; Hubele, 1994). Industrial Technology is one of these departments.

Geographically Purdue University is located in north central Indiana in the city of West Lafayette. There are over 40,000 students on the West Lafayette main campus. The University is classified as a Research I University (Res I). It has many undergraduate and graduate degree programs. The population of the greater Lafayette area is over 100,000 and encompasses an area with a strong industrial base. The Industrial Technology Department offers a Bachelor of Science degree and a Master of Science in Industrial Technology degree.

This description contrasts with Bemidji State University. Located about 100 miles south of the Canadian border in northern Minnesota, Bemidji State University is a former teachers' college. The University is classified as a Master's University (MA I). The University is located in Bemidji, Minnesota and is part of the Minnesota State College and University system. The population of Bemidji is around 11,000. The University's enrollment is approximately 4,300 and over 25,000 students have graduated from the institution (Hauser, 1998). The regional population is rural, and while there is some industry, it is very limited, scattered across northern Minnesota, and usually small compared to the more industrialized Midwest near Purdue University. Many of the students are first generation university students.

Until 1998, Bemidji State University students were not required to take math unless it was required as part of their major. The Industrial Technology Department did not and does not require math as part of the department requirements. All students were required to take one academic year of science. Students could take biology, physics, chemistry, geology, or physical science for non-science majors. The Industrial Technology Department did not require a specific science sequence but physics and chemistry were recommended. Also, computer science was not and is still not required.

Bemidji State University has graduated over 2000 students from the Industrial Technology Department since its beginning as an Industrial Arts program. The graduates come from a department that is one of the largest on the Bemidji State University campus with approximately 250 majors. In the Industrial Technology Department, there are four programs. They are Design Technology program, Industrial Technology Teacher Education program, Vocational Education program, and Industrial Technology program. Within the Industrial

Technology program, there are six emphasis areas. These emphasis areas are Industrial Design Management, Model Making, Graphic Design Management, Construction Management, Manufacturing Management, and Manufacturing Technology. The only graduate program is in Industrial Technology Teacher Education.

The data used in this article focuses on the Manufacturing Management and Manufacturing Technology emphasis area graduates because these two emphases most parallel the offerings at Purdue University.

Bemidji State University and Purdue University differ in Carnegie Classification (carnegiefoundation), size, regional location, industrial base, and background of students. Table 1 compares their curricula. The control of the course of study by the student is more structured at Purdue University (http://www.purdue.edu/). Bemidji State University students are reasonably free to select 32.8% of the total credits (Hauser, 1998). Of the 32.8%, 16.4% must be selected from the liberal education requirements (over 170 courses). This 32.8% compares to only 12.5% Free Electives in the Industrial Technology program at Purdue University. The other 16.4% of the 32.8% can be almost any offered class. Computer Science courses are not required in the Industrial Technology program at Bemidji State University. In general, the Industrial Technology program at Purdue University requires more credits in math and science than Bemidji State University. It is the purpose of this study to identify the job titles of the graduates and compare the job titles of graduates at these two different universities.

Table 1. Comparison by Area of Instruction, 1999 Catalogues.

Areas of instruction	Bemidji State University Semester Credits		Purdue University Semester Credits	
English	8	6.3%	6*	5.0%
Math	3	2.3%	5**	4.2%
Science	7	5.5%	10**	8.3%
Computer Science	0	0%	6**	5.0%
Free Electives	42	32.8%	15	12.5%
Required in Major	68	53.1%	63***	52.5%
Technical Electives	0	0%	15	12.5%
Total	128	100%	120	100%

*Option to take 3 Cr Business Writing or Speech Communications

** Option to take a 3 CR Math, Science, or Computer Science

*** Includes the 3 CR from the ** option to take a 3 CR Math, Science, or Computer Science

Methodology

Population

The population for this study included bachelor degree recipients from the Industrial Technology Program in the Industrial Technology Department with Manufacturing Management and Manufacturing Technology emphasis areas at Bemidji State University and the Industrial Technology Department in the School of Technology at Purdue University. The graduates from the Industrial Technology Program in the Industrial Technology Department at Bemidji State University were selected from the Industrial Technology Program in the period from 1989–fall quarter of 1994. From this sample of 230 graduates, 30 respondents were identified from manufacturing. The bachelor graduates from the Industrial Technology Department at Purdue University were selected from those who had graduated between the period of 1988 – 1992 (Brauer, 1993). Since the program at Purdue University does not have emphasis areas, it was not necessary to identify emphasis areas. Therefore, a random selection was made from these graduates to form a sample of 100 individuals.

Research Design

In the Bemidji State University study, an instrument was developed as part of an alumni survey for the University's Industrial Technology Program. This questionnaire was reviewed, edited, and approved by three department faculty. The questionnaire at Purdue University was developed to investigate a master's program while the questionnaire at Bemidji State University was developed to gather data as part of an alumni review for program analysis. While there were differences between the two questionnaires regarding the researcher's particular goals, both questionnaires surveyed alumni and included a question asking for the respondent's job title.

Data Collection

At Purdue University, alumni questionnaires were mailed to a random sample from the Alumni Association mailing list representing the Industrial Technology Department. Included with the questionnaire was a personalized cover letter explaining the purpose of the survey and why it was important for the reader to fill in and return the questionnaire in a timely fashion (Brauer, 1993). A second mailing was conducted after 14 days. This mailing was conducted in the same manner as the first mailing.

The Bemidji State University alumni questionnaires were mailed to graduates from the Industrial Technology Program. These alumni were from all the emphasis areas. Graduates with Manufacturing Management and Manufacturing Technology emphasis areas were identified from the responses to the survey. Included with the questionnaire was a personalized cover letter explaining the purpose of the survey, and why it was important for the reader to fill in and return the questionnaire in a timely fashion. A second mailing was not performed.

Results and Analysis

The responses consisted of self-report responses. The data recorded were the job titles of the respondents. Percentages were used to describe the size of the groups.

An overall response rate from the Purdue alumni was 45 percent. The response rate from Bemidji State University Industrial Technology Program alumni was 40 percent.

The self reported job titles were divided into similar groups. These title groups were engineer, manager/supervisor, sales, professional, and miscellaneous. Job titles were placed into groups based on common keywords. Titles with the singular term engineer in the title or the first of two terms were placed into the engineer group. Titles placed into the manager/supervisor group were placed in the group if the job title's first or second term was manager or supervisor, but engineer was not present, in the title. In addition, titles with the term coordinator were placed in the manager/supervisor group. Titles placed in the professional group were titles typical of specific career positions. The miscellaneous group contained titles that did not readily fit into one of the groups.

Percentages were calculated to determine the percent of titles in each group (Table 2). The percentages in each grouping comparing Purdue graduates and Bemidji State graduates were similar. Approximately 71% and 76% respectively, of the graduates were in the engineer and manager/supervisor groups.

Implications

The purposes of this article were to present the job titles of Industrial Technology graduates and compare the job titles of graduates from a Bemidji State University with the job titles of graduates from Purdue University. It should be noted that descriptions of job tasks would be more genuine than job titles but job tasks were not available. The differences in curriculum, as well as their many other differences such as Carnegie Classification, size, and location might lead one to suspect that the graduates would have different job titles.

Based on an examination of the data, the following conclusions were derived. There were similarities in the job titles of the graduates. From the data, 33% of the Industrial Technology bachelor degree recipients from Purdue University and Bemidji State University had engineering titled positions; 38% and 43% respectively had manager/supervisor positions; 14% and 13% had professional positions; and 14% and 10% were in the miscellaneous group. Furthermore, it is apparent that Industrial Technology bachelor degree recipients secure the largest percentage of positions in the engineering and manager/supervisor job title categories.

Since Industrial Technologist is not a common job title, the actual bachelor degree obtained by the individual is obscured by the job title. Typical job titles include industrial engineer, production supervisor, manufacturing engineer, and variations of these titles (Table 2).

The data suggests that a more structured Industrial Technology degree program with more credits directly related to Industrial Technology (much like Purdue University with its 12.5% free electives) and an Industrial Technology degree program with a more open degree program with a larger liberal education requirement (32.8%) were both effective in securing the same or similarly titled jobs. In addition, the job title similarities may indicate that school size, regional locations, industrial base, and student background do not affect job titles of Industrial Technology bachelor degree recipients.

In addition, differences in the curricula are in the areas of math and computer science. During the period in which these graduates were surveyed, the Industrial Technology program graduates at Bemidji

Table 2. Job Titles Compared for IT Graduates.

%	Purdue University	%	Bemidji State University
33	Engineer 1. Clinical Engineer 2. Control Engineer - Staff Associate 3. Design and Fabrication Engineer 4. Detail/Design Engineer 5. Facilities Engineer 6. Field Engineer 7. Industrial Engineer 8. Industrial Engineer 9. Manufacturing Engineer 10. Manufacturing Engineer 11. Process Engineer 12. Production Engineer 13. Quality Engineer 14. Safety Engineer	33	Engineer 1. Current Product Engineer 2. Manufacturing Engineer 3. Project Engineer – QA 4. Project Engineer 5. Manufacturing Engineer 6. Staff Mining Engineer 7. Process Engineer 8. Manufacturing Engineer 9. Materials Engineer 10. Site Safety Engineer
38	Manager / Supervisor 1. Manufacturing and Engineering Manager 2. Quality Assurance Manager 3. Quality Control Manager 4. Shift Manager – Assistant Coordinator 5. Assembly Foreman 6. Fabrication Supervisor 7. Foreman (First-line Manager) 8. Maintenance Supervisor 9. Operations Supervisor 10. Production Supervisor 11. Production Supervisor 12. Quality Assurance Supervisor 13. Site Supervisor 14. Sales Coordinator 15. Production Team Leader 16. Manager	43	Manager / Supervisor 1. Plant Manager 2. General Manager/Manufacturing Engineer 3. Plant Manager/Engineer 4. QC & Production Manager 5. Senior Project Coordinator 6. Predictive/Preventative Maintenance Coordinator 7. Project Coordinator 8. Manufacturing Engineering Director 9. Plant Supervisor 10. Electrical Supervisor 11. Roughmill Supervisor 12. QC Supervisor/Engineer 13. Instrumentation Supervisor
14	Professions 1. Drafting Technician 2. Fire-fighter/EMT 3. Illustrator 4. Naval Flight Officer 5. Quality Control Technician 6. Scientist	13	Professions 1. Mold Maker/ R&D 2. Pipe Fitter 3. Production Technician 4. Safety Coordinator – Plant Millwright
14	Miscellaneous 1. Administrative Assistant 2. Graduate Research Assistant 3. In-Plant Technician Trainee 4. Logistic Analyst 5. Production Scheduling 6. Sales Representative	10	Miscellaneous 1. Planner 2. Operator 3. Maintenance Planner

State University may not have had any math. Data are not readily available to indicate how many and which students from the survey did not complete a math course as part of their University experience. In the area of computer science, Industrial Technology program graduates at Bemidji State University are not required to take any computer science classes, while those at Purdue University take at least 6 credits. Curricula during this period have changed somewhat over time; however, the overall structure of the degree programs has not changed substantially. Research comparing the job titles of graduates from current catalogues might be useful in identifying the impacts of these differences in math and computer science.

Job titles do not describe the job that is performed, pay, or other parameters of particular positions. They are at best a rough indicator of responsibilities and duties. A study of specific job tasks is an area for further study. Furthermore, a follow-up investigation into the exact backgrounds of the students may be useful.

This article does provide a glimpse of bachelor graduates from two different Industrial Technology programs. Both Industrial Technology programs have graduates at about the same amount in similarly titled jobs. Assuming that most graduates obtain jobs in their region, one could speculate that the recommended National Association of Industrial Technology (NAIT) curriculum should continue to provide flexibility for each institution to fulfill that particular institution's regional needs. In addition, the NAIT accreditation standards should continue to provide opportunity for dissimilar institutions to be eligible for accreditation.

The job titles reported from these graduates also signal this: Industrial Technology program graduates obtain a majority of positions which are engineering and manager oriented. Based on the number of graduates from the many Industrial Technology Programs throughout the nation, the next time you meet a manager or engineer you may well be talking to an Industrial Technologist.

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At-Risk Students and Technology Education: A Qualitative Study

Phillip L. Cardon

Recently, there has been a resurgence of interest regarding at-risk students in secondary education. Most studies, in the area of retaining at-risk students in school, focus on vocational training, innovative academic programs, and learning styles (Boutin & Chinien, 1998; Engman, 1989; Friedenberg, 1999). Some studies discuss the importance of schools meeting the needs and interests of these students through interesting programs in order to retain them in secondary education (Ainley, Batten, & Miller, 1984a, 1984b; Ainley, Foreman, & Sheret, 1991). Other studies discuss the importance of teaching students according to their learning styles (Dunn, Dunn, & Price, 1989; O'Neil, 1990). Although there has been much research performed regarding at-risk students in secondary education, few studies address the reasons why at-risk students want to remain in school (Damico, 1989; Taylor-Dunlop & Norton, 1997).

To clarify the word "at risk," the following definition of an at-risk student was given by McCann and Austin (1988) who define the at-risk student with three characteristics:

> – First, they are students who are at risk of not achieving the goals of education, of not meeting local and state standards of high school graduation, and of not acquiring the knowledge, skills, and dispositions to become productive members of society (receiving less than 2.00 grade point average).
> – Second, they are children who exhibit behaviors that interfere with themselves and others attaining an education, requiring disciplinary action (at least three incidents).
> – Third, they are those whose family background characteristics may place them at risk (low income to below poverty level, non-English native speaker, etc.). (p. 1-2)

Batsche (1985) successfully compiled the common characteristics that define at-risk students.

> Characteristics of the Individual
> – history of school absenteeism,
> – poor grades,
> – low math and reading scores,
> – low self-concept,
> – history of behavioral problems,
> – inability to identify with other people,
> – employed full time while in school,
> – low socioeconomic background,
> – more males than females,
> – feel alienated and isolated. (p. 1)
>
> Characteristics of the Family
> – family with several siblings,
> – father absent from the home,
> – father unemployed,
> – father did not complete high school,
> – mother absent from the home in early adolescence,
> – little reading material in the home. (p. 1)

The preceding characteristics were utilized in identifying the at-risk students to be used in the study.

According to Damico (1989), social learning factors affect the at-risk student's desires to remain in school. These factors include the at-risk student's determination to succeed, the student's relationship with his or her teachers, and extracurricular activities in which the student participated. At-risk students who had good social support, both from within and from without school, showed interest in remaining in school. This is supported by Ainley, Foreman, &

Sheret (1991) who mentioned that successful educational experiences and a positive view of the school assisted at-risk students to remain in school. A study regarding the reasons why at-risk students remain in school was performed by Power (1984). This study found that the at-risk student's individual achievement level and academic performance was directly related to the student's decision to remain in school. Additional studies found that achievement and satisfaction with school had a significant impact on at-risk students' decisions to remain in school (Ainley, 1994; Ainley & Sheret, 1992; McMillan & Reed, 1993; Rosier, 1978; Williams, Clancy, Batten, & Girling-Butcher, 1980).

The previous studies are supported by a study performed by Taylor-Dunlop and Norton (1997) that included eleven at-risk female students aged 15 to 17 in New York State. The three Latino, two Caucasian, and six African-American at-risk students participated in focus groups, individual interviews, and small group meetings.

The results of Taylor-Dunlop and Norton's study supported the concept of having supportive links between at-risk students and school. These links include relationships between at-risk students and their teachers, counselors, and friends. The students also indicated that they came to school because they enjoyed math and hands-on courses (i.e. art). Taylor-Dunlop and Norton explained that

> The students' criteria for a favorite course appeared to depend on the amount of self-expression they could achieve in the class, whether it offered practical application, and whether the subject matter came to them easily, giving them a feeling of mastery or being smart. (p. 277)

The study performed by Taylor-Dunlop and Norton (1997) supported this study since at-risk students showed a desire to attend math and hands-on courses like art. Although centered around a curriculum of construction, manufacturing, communication, and transportation/power/ energy, technology education courses are similar to art courses because they focus on teaching students through hands-on activities.

Although technology education programs have historically attracted at-risk students, they have received little attention regarding their influence on at-risk students (Cottingham, 1990). In addition, there have been no studies performed regarding at-risk students' views of technology education and why they desire to take technology education courses.

Purpose of the Study

The enrollment of at-risk students in technology education courses is pervasive throughout the country. However, little is known about why at–risk students would want to take technology education courses, how they value these courses, and the value of technology education courses helps them remain in school. Therefore, the purpose of this qualitative case study was to explore, describe, and examine how at-risk students experience and interact with the technology education curriculum.

Conceptual Framework

Learning within the technology education environment includes three primary learning theories: construction of knowledge, problem solving, and hands-on learning theories (Herschbach, 1998). According to Nuthall (1997), the construction of knowledge learning theory is an important part of education. Piaget (1978) argued that what is internalized is not the behavior but the system that organizes the specific acts involved. In the technology education perspective, Herschbach (1998) stated that,

> The design of instruction based on cognitive the ory shifts instructional emphasis from the passive learning of formally organized, specific content to the active acquisition and use of knowledge. Instructional interventions are designed to assist students to construct meaning, not to memorize information – hence, its usefulness in designing integrative and higher-order learning. (p. 55)

Herschbach describes how important it is for students to actually work with the knowledge and see how it relates to previous knowledge they have gained, and make sense of it and how it fits into their lives (Idol & Jones, 1990; Resnick, 1989; Streibel, 1995; Winn, 1991).

Closely associated with the construction of knowledge, the problem-solving learning theory plays an important role in the contemporary technology education curriculum. The problem-solving learning theory comprises the cognition, guided practice, and automated behavior stages of expertise in problem solving (Johnson, 1988). Through interaction with problems in technology education curricula, students achieve learning and satisfaction

(Johnson, 1988).

Finally, hands-on learning theory plays an important role in technology education curriculum (Korwin and Jones, 1990). As a hands-on subject, technology education demands that students interact with their learning environment. Gokhale (1996) defined hands-on learning theory as follows: “The basic premise of this theory is that students learn as a result of doing or experiencing things in the world, and learning occurs when mental activity is suffused with physical activity” (p. 38). Dewey (1900) believed that, through hands-on activities, students could combine intellectual stimulation with activities that expanded learning.

Method of Research

This research was performed using case study, participant-observation qualitative research methodology. A pilot study was performed for the development of observation techniques and questions for the study, and for me to see some of the views of at-risk students regarding technology education. Support for the case study design used in this study included first, the detailed examination of at-risk students in a technology education environment (Merriam, 1988). Second, I needed to see and understand the interactions between the at-risk students and the technology education curriculum.

After reviewing various sampling techniques used in qualitative research, purposeful sampling was chosen for this study (Merriam, 1998; Patton, 1990). The location was different from the one used for the pre-study, supporting a one-teacher technology education program. The eight at-risk student participants in the study were chosen from a survey of technology course and a power/energy/transportation course containing mostly at-risk students. If the student in question demonstrated most of the characteristics listed by Batsche (1985), then he or she was considered a possible candidate for the study.

Procedures

In this study, I refer to “data” as “evidence.” Participant observation and interviews (interactive methods) and document evaluation (non-interactive method) were utilized in obtaining the evidence for the study. These three methods helped to triangulate or check the accuracy of the evidence (Lincoln & Guba, 1985). Other methods used in the study to assist in the triangulation of evidence include member checking (Lincoln & Guba, 1985; Bogdan & Biklen, 1998; Scheurich, 1996) and the establishing of credibility through patterns (Scheurich, 1996). This was done to counteract the novelty effect and observer bias (Gay, 1996).

The evidence was obtained during observations and interviews through the use of instruments developed from the pre-study and from the literature review. The observations were performed daily for six months, with interviews performed at times convenient to each student participant. The satisfaction of evidence collection was completed, as described by Lincoln & Guba (1985), when the sources of information were exhausted, new categories of information were unavailable, and evidence became predictable. Following the study, the evidence was organized and compiled into the NUD*IST(r) qualitative evidence evaluation program.

Evidence Evaluation Procedures

In the evidence evaluation phase of the project, the NUD*IST(r) software was used to search for emerging themes and compile the evidence according to these themes. Three categories, construction of knowledge, problem solving, and hands-on learning, became evident. Under the construction of knowledge category, the subcategories of clarification, association, and knowledge development were established. The problem-solving category contained the subcategories of novice, intermediate, and advanced problem solver. The third category, hands-on learning, contained the subcategories of facilitating learning, learning styles, and life skills. From these categories, three theories of learning, the construction of knowledge theory, the problem-solving learning theory, and the hands-on learning theory, were linked to the at-risk students’ experiences. A fourth category, integration of subjects, was also apparent in the evidence, and contained subcategories of mathematics, science, and technology. A fifth category, remaining in school, was also evident, but was not considered to be purposefully influenced by the technology education program. The subcategories of remaining in school include hands-on curriculum, successful educational experiences, and reasons for remaining in school.

These categories were formed according to guidelines set forth by Merriam (1988). These guidelines suggest that 1) the purpose of the research is reflected in the categories, 2) all related items can be put in a category, 3) no items are included in more than one category, 4) each category is separate and independent of the others, and 5) the categories came from a common base of classification. Once the categories were formed, the evidence was then placed in its relative category within the NUD*IST(r) program (Scheurich, 1996).

Establishing Credibility

Credibility is based on the validity and reliability of the instrument or instruments used and the internal validity of the study. Credibility is supported by prolonged engagement, persistent observation, and triangulation (Lincoln & Guba, 1985). All three of these factors were used to increase the credibility of this study. First, the study was performed over a six-month period of time. Second, intense observation and evidence collection was performed once the subjects were identified and secured. Finally, evidences from observations, interviews, and document evaluation were used to help support the trustworthiness of the findings.

Findings

As a theoretically-based study, the evidence, evaluated according to the construction of knowledge, problem solving, and hands-on learning theories, contained consistencies found among the at-risk students. Findings indicated that the construction of knowledge was a part of the curriculum in helping the at-risk students to learn the concepts regarding planning, materials, and processes, and to give the students the experience of working with these concepts (Dewey, 1900; Towers, Lux, & Ray, 1966). Evidence to support the problem-solving theory was not as consistent among the participants as the construction of knowledge or hands-on learning theories, but the evidence did demonstrate the importance of learning the concepts of planning, materials, and processes. The evidence was consistent among the at-risk students with regard to the hands-on learning theory. The students indicated that they learned better through hands-on learning methods than through book work or lecture methods (Dewey, 1900, 1916, 1938; Herschbach, 1996). Examples of evidence from each student in Table 1 helped support the finding, and demonstrated consistency among the students.

As the evidence was evaluated according to theories, consistency was found between the at-risk students in both the construction of knowledge and hands-on learning theories. There was inconsistency found in the problem-solving theory between two students in the survey of technology education course and three students in the power/energy/transportation course. It was determined that the difference was partially due to the fact that the two students in the survey of technology education course did not have

Table 1. Cross–theory Analysis.

Theories	Evidence from the Students				
	Rick	John	Henry	Nick	Price
Construction of Knowledge	“Ah. So the different drawings represent different views or perspectives.”	“Well, I learned how to do things a little better... I know how to fix something.”	“I changed the drill bit to a smaller size so that the walls of the base will not crack.”	“But it doesn’t show how far the holes are from the sides.”	“How to use a lot of stuff that can help you if you want to make somethin’.”
Problem Solving	“If I could just get the fenders to stay on the car.”	When the robotic arm wasn’t working, “I sat down with my partner to find a solution.”	“If Mr. Harman would let me do what I wanted, I’d make it smaller and lighter.”	“I thought that we should design and use a robot hand that has split fingers.”	“It’s kinda like you gotta know math. If you don’t learn math, you won’t able to do nothin’ in here.”
Hands-on Learning	“We do more, like, hands–on work, and, like, you get to work in the shop and work with tools and stuff.”	“We do more hands-on . . . special curricular or whatever. I think we do more of that than just (reading) text books.”	“Hey man, it’s real interesting. I mean, here’s lots of things to learn and do with your hands.”	“You get a lot of hands–on experience. It’s not one of those classes where they just tell you to look at the book.”	“Information like and electricity. A lot of stuff that can help you if you want to make somethin’.”

as good of a foundation of planning, materials, and processes as the students in the power/energy/transportation course (Berkemer, 1989).

From the evidence, there seemed to be a clear link between the construction of knowledge theory and the problem-solving theory. This link was described by Berkemer (1989) and Johnson (1988), who explained that the knowledge of planning, materials, and processes was vital for the success of students in problem-solving activities. In addition, while engaged in a problem-solving activity, students were constantly constructing new knowledge as they work through problems (Brown, Collins, & Duguid, 1989, Dewey, 1900).

The link between the problem-solving theory and the hands-on learning theory was also apparent in the evidence and in the literature. The technology education curriculum in the study required students to work interactively with tools, planning, materials, and processes as they solve problems (Sanders, 1993; Gokhale, 1996).

The evidence helped to establish a link between the hands-on learning theory and the construction of knowledge theory. It was found that knowledge construction for students in the technology education program involved the use of hands-on methods in order to learn how to work with the materials and processes of industry (Dewey, 1900; Herschbach, 1996). Also during the study, there was evidence of the integration of knowledge between these subjects, and the influence of the technology education program in assisting students to understand mathematics and science concepts (Korwin and Jones, 1990).

Evidence was obtained during the study that emphasized the importance of life skills in the lives of the students. During interviews and observations, the students indicated that one of the reasons they took the technology education course was to obtain knowledge and skills regarding technology that could help them in life. Much of the evidence reflected the students' desires to know how to maintain a home or a vehicle (Dewey, 1900, 1916, 1938; Shield, 1996).

In the study, the at-risk students found school in general to be boring and academically focused. Although the students in the study had difficulty experiencing achievement and success in their other subjects, they saw success and achievement in the technology education program.

Not only did the students enjoy school more when they had successful experiences, they also indicated that the technology education program had a profound influence in their decision to remain in school. In the interviews, five of the eight students mentioned they would not be in school if it were not for successful experiences and hands-on learning activities they experienced in the technology education program.

Discussion

Questions of the Study

There were two primary questions that guided this study of how at-risk students view technology. These are "How do at-risk students respond to a technology education program?" and "Why do at-risk students enroll in technology education courses?" The first question related not only to the experiences and knowledge the students gained while in the present technology education course, but also was related to their previous knowledge and experiences. Most of the students had some experience with technology education in junior high or middle school, and reflected on this knowledge in their interviews.

The knowledge they obtained from the high school technology education program in the study allowed the students to construct new knowledge and build upon the knowledge they had previously obtained. This knowledge was used to help the students to perform better during problem-solving activities.

The responses of the students to the problem-solving activities in the power/energy/transportation course were very positive. The students demonstrated a sincere desire to work hard and complete their projects, competing for the best designed robotic hand or the highest flying water bottle rocket. The literature regarding at-risk students revealed they perform better when they are in an environment that helps them to be successful (Midkiff, 1991).

The observations and interviews revealed that the students preferred hands-on learning in a curriculum to the traditional book and lecture method. The students performed well in the technology education courses. However, the students did not perform as well in the other school subjects. Evidence from the students indicated the possibility that a lack of hands-on experiences in other courses could hinder their performance in those courses (Midkiff, 1991).

The second question of the study focused on the reasons behind a student's decision to enroll in a technology education course. Responses included (1) they had a positive experience in a junior high or middle school technology education course and wanted to enroll in another technology education course (Midkiff, 1991), (2) they wanted to learn more about technology, and (3) five of the eight students said that if they had not been allowed to enroll in the technology education course, they would have dropped out of school.

Practical Implications

What do the findings in this study tell us about teachers of at-risk students? Teachers of at-risk students could consider including hands-on and problem-solving learning methods in their curriculum. This would allow the at-risk students to achieve success.

What do the findings in this study tell us about the curriculum in schools? Evidence exists from studies that indicates curriculum factors may influence at-risk students to remain in school (Ainley, 1989). According to Ainley, Batten, and Miller (1984b), schools that offer hands-on learning programs demonstrate higher graduation rates than schools who focus on lecture-and-examination subjects geared to university entrance.

The findings in this study corroborated with the evidence from existing research regarding at-risk students and the use of hands-on learning curriculum in the classroom. Developers of curricula could consider including hands-on learning theory in the curricula they develop in order to assist at-risk students in learning the material and performing better in the courses (Dunn, Dunn, & Price, 1989; Midkiff, 1991).

The evidence in this study also suggested that the integration of mathematics, science, and technology education should be considered when developing curricula for each of these subjects. This is supported by extensive research in the fields of mathematics, science, and technology education curricula (Bredderman, 1985; Johnson, 1989; Korwin & Jones, 1990; LaPorte & Sanders, 1995; Simon, 1991)

What do the findings in this study tell us about the curriculum in technology education programs? Evidence from this study regarding at-risk students and technology education programs suggested that technology education curriculum should continue to include hands-on learning methods associated with problem-solving activities. In this type of curriculum, at-risk students would be able to engage in units of study that would allow them to have successful experiences (Cole & Griffin, 1987; Van Haneghan, Barron, Williams, Vye, & Bransford, 1992). Evidence relating to the influence of the technology education program on students' performance in other subjects suggested that the technology education curriculum could play an important part in the instruction of students regarding other subjects, such as mathematics and science.

As discussed in the review of literature, at-risk students remained in school longer when given opportunities to experience success and achievement (Ainley, Foreman, and Sheret, 1991; Beck & Muia, 1980). Evidence from the students in the study corroborated with the literature and demonstrated that at-risk students did enjoy school more when they experienced success. In this light, technology education programs may be able to fill a role to provide incentive for at-risk students to remain in school.

Theoretical Implications

Limitations of the Study. As with all research studies, there are limitations that exist. This research study was qualitative in nature and focused on eight at-risk students in a technology education program. Therefore, the study is limited to the male at-risk students in the study, in the technology education program in which the study was conducted. In addition, the subjects were not randomly selected, so they were not representative of the class. In other words, the results of the study are not generalizable to any at-risk students outside the study.

Although the findings are limited to the population of this study, generalizations may be made by the individual readers. Fraenkel and Wallen (1996) discussed the generalizations made in a qualitative study.

> In a qualitative study, . . . the researcher may also generalize, but it is much more likely that any generalizing to be done will be by interested practitioners–by individuals who are in situations similar to the practitioner, rather than the researcher, who judges the applicability of the researcher's findings and conclusions, who determines whether the researcher's findings fit his or her situation. (p. 465)

Another limitation of the study deals with the manner in which I distanced myself from the students in the observations and activities. I kept myself aloof from the students in order to maintain a more objective description of the evidence. This may limit the amount of in-depth information obtained regarding the experiences of the students.

A last limitation of the study is that I was limited in the number of courses that I could observe. Due to my schedule, I was limited to observing students in the third and fourth periods. I was unable to view at-risk students in courses scheduled in the fifth through ninth periods.

Implications for Further Research. Longitudinal research should be conducted regarding the utilization of hands-on learning and problem-solving methods for teaching at-risk students, not only in technology education, but in other academic subjects as well. Further research is needed to help determine curricula that can assist at-risk students to experience success in school.

Another method for studying this issue would be to ask teachers in the school to participate in hands-on activities that relate to their subject. Through a study of the way at-risk students respond to hands-on learning activities in regular school subjects, teachers could increase the number of at-risk students retained in school. Also, more research needs to be performed regarding the ways in which at-risk students view technology education programs and other school subjects. This would add to the existing literature and research base, and assist teachers, administrators, and college professors in the development of curricula for at-risk students. Further research needs to be performed regarding the enrollment of at-risk students in technology education courses with regard to their prior experience and possible future experiences. This could assist parents and counselors with helping at-risk students to select courses that will help them to learn through hands-on learning methods.

Also, research regarding the integration of mathematics, science, and technology education as curriculum for at-risk students should be explored. Evidence from this study suggests that the integration of subjects in a hands-on learning environment could benefit at-risk students. The duplication of this research study in another part of the country would help to confirm the evidence found in this study. In addition, a duplication of this study might reveal evidence that was not obtained in this study. On a grander scale, quantitative local, area, and national research regarding curricula for at-risk students should be performed. This would help to determine the influence of technology education programs with regard to at-risk students. In addition, it would assist curriculum developers in the technology education field to consider at-risk students when developing technology education curriculum.

Phillip Cardon's research centers on at-risk students and their efficacy in school. this is Cardon's second publication in The Journal of Technology Studies.

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Comparing the Success of Students Enrolled in Distance Edcuation Courses vs. Face–to–Face Classrooms

Michael K. Swan and Diane H. Jackman

Introduction

As we enter the 21st century and embark further into the information age, many institutions and schools are turning to technology to enhance their programs and to expand their horizons. Geography is no longer a barrier for preventing people from accessing information and education (Dixon, 1996). Rapid developments in telecommunication technologies, tightening budgets, and changes in student demographics have stimulated an increasing interest in distance education in all educational settings (Honeyman & Miller, 1993). Through the use of videoconferencing, computers, modems, and the Internet, schools are able to deliver courses and degree programs to students in distance locations without requiring them to set foot in a traditional classroom. Virtual environments, instant access to information, and talking machines make the Jetsons' world seem more like a nearby reality rather than fiction.

Distance education is an emerging technology intended to deliver both resident and remote site instruction. Educators who use distance education must provide educational experiences to off-site students that will equal resident education in terms of quality and quantity. Both resident and distance education are intended to provide students with valid, useful information that promotes learning. Resident or host-site education occurs when the instructor and students meet at a predetermined location, thus providing easy face-to-face interaction. The instructor can be in different buildings, cities, counties, states, or even countries. According to Swan and Brehmer (1994), distance education refers to "the simultaneous delivery of instruction from a host site or classroom to remote site(s), coupled with real time live audio and real time live video interaction between teacher and student(s)-not correspondence, video, or internet courses" (p. 18) Distance education, according to the U.S. Department of Agriculture, is a process to create and provide access to learning when the source of information and the learners are separated by time and distance, or both. In other words, it is the process of designing educational experiences that best suit the learner who may not be in a classroom with an instructor at a specific time. Murphy (1997) defined distance education as a premeditated and persistent attempt to promote learning in an environment that includes geographic, temporal, or pedagogical distance.

Swan (1995) noted that advancements in communications technology have dissolved some of the major distinguishable characteristics between distance education and traditional education. According to Swan and Jackman (1996), strategies of teaching at a distance and host site are converging because traditional teaching strategies are being abandoned or modified in favor of a problem-based, resource-based, or activity-based approach that de-emphasizes the teacher as the main source of knowledge. In 1990, Moore and Thompson analyzed resident and distance education and developed a framework for determining the relationship between the two methods of instructional delivery. They noted that developing technology will eventually merge distance education with the traditional approach so that distinctions cannot be made between the two methods. However, Kelly (1990) indicated that the transition from resident instruction in the traditional classroom to distance education requires educators to develop new skills in instructional strategies, methods of teaching, timing, teacher/student interaction, feedback, printed supplemental materials, and evaluation.

Souder (1993) compared distance learners and traditional host-site learners. The distance education learners performed better than the host-site learners in several areas or fields of study, including exams and homework assignments. This finding was attributed to the extraordinary commitment, higher maturity level, and motivation of the distance learner. However, this finding is contrary to other evidence that distance learners are at a disadvantage in their learning experience, especially in the evaluation of their cognitive performance (Moore & Thompson, 1990).

Although there is a controversy over the usefulness of traditional indicators such as grade point averages (GPAs) and standardized test scores in determining an individual's rank in a competitive admissions process, the historical evidence indicates that such information is valuable and predictive if used in a balanced and equitable manner (Lewis, Alexandria, & Farris, 1998). There have been challenges to admissions committees to place less emphasis on traditional admissions variables such as GPAs and standardized test scores and more emphasis on subjective evaluations.

The increasing availability of telecommunications has provided vocational or applied education faculty with unique opportunities to plan and deliver distance education courses and programs. Vocational education students are also enrolling in more distance courses and programs due to availability, time, and place. However, there is a lack of studies that compare student achievement by students receiving instruction via distance technology versus students receiving the same instruction through the traditional resident, host-site, classroom setting.

Purpose/Objectives

The purpose of the study was to ascertain if students' achievement differences existed in courses delivered via distance education. Specific research objectives were as follows:

1. Describe students' enrolled, in distance education courses, both remote site and host site, on selected demographic characteristics.

2. Ascertain if differences existed between remote-site and host-site students' achievement based on GPA obtained by grade level.

3. Ascertain if differences existed between remote-site and host-site students' achievement (final grade received) based on individual course success.

Methodology

Definitions

Host site: The school where the instructing teacher is located and where the course originates during the course sessions. The teacher is physically in the classroom with the students.

Remote site: The classroom where the students are physically in the school setting but the instructing teacher is teaching students via an electronic format. The teacher is *not* physically in the classroom with the students.

Populations

The population of remote-site and host-site schools was identified from an alphabetical list of secondary schools utilizing distance education technologies supplied by the State Department of Public Instruction. The schools were all located within one midwestern state. Each of the identified schools' administration was asked to participate in the study. From the total list of schools using distance education, the total population of schools willing to participate were identified (N=46). From this revised list of schools, a study sample was selected using appropriate cluster sampling methods outlined by Wiersma (1995).

As each secondary school was selected, all classes being offered via distance education from that school were selected for this study. Each student in the study (N=623) was enrolled in at least one course being offered via distance education. To retain the confidentiality of the student, administrators or the assigned school representative was asked to assign an identification number to each student. This number was used to report all data concerning that student. The researcher did not know student's name, only her assigned number.

Instrumentation/Data Collection

The study instrument, adapted from the Souder study (1993), was completed from students' records by the administration or assigned school representative. The instrument was assessed for content and face validity by graduate students, teacher educators, and state supervisors in vocational education. This procedure was followed because more than one person in a school was responsible for providing the data required by the researcher. Reliability of the instrument was .89 (Cronbach's alpha coefficient). They were asked to report gender, grade level of student, period(s) taking distance education courses, name(s) of specific distance education course(s), location of student (remote or host site), total daily assignment scores, exams and/or quiz scores, and final exam score. All grades reported were based on or converted to a 0 to 100 point system. If conversions were made, they were made by the administration or assigned school representative using a scale provided by the researcher. This grading scale was one recommended by the state superintendents and principals association.

Data Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS Version 6.1) for Windows. Data were summarized using descriptive statistics. Frequencies, percentages, means, and standard deviations were utilized to analyze and describe findings. One-way analysis of variance was used to analyze differences between the grade levels of students, the location of student, and gender. All tests were run at the .05 alpha level.

Results

Objective 1: Demographic Characteristics

Demographically, students in the study were predominately located at remote sites: 424 at remote sites (68.1%) and 199 at host sites (31.9%). The students in this study included 378 female students (60.7%) and 245 male students (39.3%). The study identified 10 individual courses being offered via distance education. One course was eliminated from the study because no results were made available to the researcher. The total number of students by grade level included:
9th = 56 (9%),
10th = 126 (20.2%),
11th = 161 (25.9%),
and 12th = 280 (44.9%).

As shown in Table 1, the study group is divided into groups identified by specific course name and by location receiving the course. Frequencies and percentages are used to identify students enrolled in distance education courses at all sites in the study. Students in the 12th grade reported taking more distance education courses than did 9th grade students.

Table 1. Individual Course Enrollment Frequencies and Percentages.

Course Name	All Sites		Host Site		Remote Site	
	N	%	N	%	N	%
Foreign language	231	37.1	91	39.4	140	60.6
Ag business mgt.	77	12.4	3	3.9	74	96.1
Vocational marketing	21	3.4	14	66.7	7	33.3
Natural resources	42	6.8	4	9.5	38	90.5
Math-calculus	119	19.1	63	52.9	56	47.1
Chemistry	70	11.2	9	12.9	61	87.1
Art	14	2.2	5	35.7	9	64.3
Statistics	14	2.2	6	42.9	8	57.1
Animal science	35	5.6	4	11.4	31	88.6
Total	623	100	199	31.9	424	68.1

Objective 2: Comparing Overall GPA's

One-way analysis of variance was used to test if differences in student achievement existed between remote-site and host-site students based on mean GPA. No significant differences were found.

Table 2 identifies the mean GPA of students located at remote sites and at host sites. The grade point averages of students enrolled in distance education courses at both the remote and host sites were very similar. This indicates that the students in this study were alike when examining academic achievement using GPAs.

Analysis of variance was used to test for differences in student achievement between grade levels based on mean GPA. Significant differences were found and the analysis of the data yielded an F value of 2.84 (p = 037). The 9th grade students earned a GPA significantly higher than 11th grade students (p = 045), and the 9th grade students earned a significantly higher GPA than did 12th-grade students

Table 2. Grade Point Average According to Location Receiving Course.

Location	N	GPA	SD
Remote site	424	3.19	.76
Host site	199	3.14	.84
Total	623	3.18	.78

(p = .005) as reported in Table 3.

What this means is that when examining GPAs within grade level, students in this study were very similar. When comparing GPAs among grade levels, differences that were not considered to be within a normal range were found. This study was not designed to determine why the differences occurred.

Objective 3: Course Differences

One-way analysis of variance was used to test if differences existed between remote-site students' GPAs and host-site students' GPAs by individual course. There were no significant differences among the two groups (remote site and host site). The analysis yielded an F value of .51 (p = .47) as reported in Table 4. Significant differences existed between the groups by grade level. The analysis yielded an F value of 12.23 (p = <.0001). Analysis of data of student achievement (GPA) by remote site or host site by individual course identified no significant differences. The analysis yielded an F value of .77 (p = .62) as reported in Table 4.

Table 3. Comparison of Students Grade Point Average by Grade Level and by Site.

Grade Level / Site	N	GPA	SD	SE
9th Total	56	3.43	.72	.09
10th Total	126	3.22	.65	.05
11th Total	161	3.18	.71	.05
12th Total	280	3.10	.87	.05

9th to 10th	p = .095
9th to 11th	p = .045*
9th to 12th	p = .005*
10th to 11th	p = .712
10th to 12th	p = .171
11th to 12th	p = .297

When comparing students' GPAs by courses differences are seen in individual courses. In all courses GPAs were identified as being significantly higher than GPAs in vocational marketing. Foreign Languages GPAs were significantly higher then GPAs in vocational marketing. GPAs in natural resources, chemistry, and Art were significantly higher than GPAs in foreign languages. GPAs in natural resources were significantly higher than GPAs in ag business mgt., math, and animal science as reported in Table 6. Significant differences were found when grouping traditional vocational courses (Ag Business Mgt., Vocational Marketing, Natural Resources, and Animal Science) together and comparing to the traditional academics in student achievement as measured by GPA. Students in traditional academic courses had a higher GPA (3.25) than did students in vocational courses (2.99 GPA). The analysis yielded an F value of 13.56 (p = .0003) as reported in Table 6.

Table 4. Analysis of Variance for Grade Point Average on Site Location and Individual Course.

Source	df	SS	MS	F	p
Site	1	.262	.262	.511	.4749
Class	8	50.194	6.274	12.231	<.0001
Site * Class	8	3.186	.398	.776	.6237

Conclusions

1. Students enrolled in distance education courses were primarily located at remote sites. Without this opportunity, most of these students (424) would not have been able to enroll in these courses. Distance education students had the opportunity to enroll in more than one distance education course.
2. As students progressed through high school, they enrolled in more courses being offered via distance education.
3. Receiving instruction by distance education resulted in no differences in GPA for all students at either remote site or host site. Students in 9 th grade did have higher GPAs than did 11th-grade and 12th-students. This may be attributed to the specific courses and complexity of courses taken by these groups of students. Twelfth-grade students located at host sites had a significantly lower GPA than 12th-grade students located at remote sites.

This area needs further analysis to determine exact reason for this occurrence.

4. Significant differences in GPA did not exist between all remote-site students and all host-site students in this study. However, it did make a difference if a student was in the same room with the teacher or if they were at a different location.

Table 5. Individual Course Success (GPA) by Host Site and Remote Site.

Course Name	Host Site N	Host Site GPA	Remote Site N	Remote Site GPA
Foreign language	91	3.29	140	3.06
Ag business mgt.	3	3.23	74	3.09
Vocational marketing	14	1.70	7	2.00
Natural resources	4	3.68	38	3.43
Math-calculus	63	3.11	56	3.21
Chemistry	9	3.57	61	3.58
Art	5	4.00	9	4.00
Statistics	6	3.50	8	3.50
Animal science	4	3.43	31	2.88

Table 6. Analysis of Variance for Grade Point Average on Academic and Vocational Courses.

Source	df	SS	MS	F	p
Between	1	8.18	8.18	13.56	.0003
Within	621	374.34	.60		

Significant differences in GPA were found when grouping students by grade level and remote site or host site. Remote site students in 9th, 10th and 12th grades had a higher GPA than did their counterparts located at the host site.

5. Individual courses being offered via distance education revealed differences in student achievement. Vocational marketing was significantly different than all other courses. After placing a telephone call to the local administrator, it seemed that the cause could have been that the teacher was new and this was the first distance education course he had taught.Generally, it did not matter if the teacher was at the remote site or host site for the instruction; student success was high or above average for all courses except one. Students taking traditional academic courses received a higher GPA than those students taking vocational courses.

6. Student success, as measured by GPAs, was above average (mean GPA whole group = 3.18) in distance education courses.

Recommendations

1. Faculty preservice and in-service programs should be developed in the appropriate use of distance education technologies.

2. Further research needs to be conducted with populations of students to determine if there are student learning style differences for those who are enrolled in distance education courses versus those electing traditional classrooms. This factor could have attributed to the success rate of students enrolled in these courses. Additionally, the quantity of distance education courses being taken by students may be a contributing factor to success. As students and teachers become more familiar with the distance delivery medium and courses more suited to the medium are offered, perhaps students' grades will improve.

3. Research should be conducted to determine which courses can best be delivered utilizing distance education technologies.

4. Research should be conducted to determine which teaching styles are best utilized to deliver distance courses.

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Industrial Research and Development Labs: How They Inform Science and Technology Curricula

Marc J. de Vries

Science and Technology Education

One of the struggles in the development of technology education is the establishment of a proper relationship between science education and technology education (de Vries, 1997). In part this is because science educators hoped to integrate technology into the school curriculum to eliminate the need for a separate area for teaching and learning about technology. This model has yielded programs often based on the "technology is applied science" paradigm. Even though this paradigm has been challenged heavily by historians and philosophers, we still encounter this model.

By contrast, since science education already is a well-established school subject, no one debates whether science should be a separate area of teaching and learning in the curriculum. But the place of technology education still requires some defense. This defense is sometimes sought by identifying a body of knowledge, a discipline, expressly for technology (either a combination of engineering disciplines or something entirely new). Some authors challenge this defense, but there is certainly evidence there are categories of knowledge in technology which differ from science (de Vries & Tamir, 1997).

This still leaves us with the question: What then is the proper relationship between science and technology education, assuming both have the right to serve as separate areas of teaching and learning in the curriculum? One way is to look at how science and technology interact in reality. In fact, we would have to find a place where people consciously try to make science and technology interact optimally. But where do we find such situations?

Industrial research laboratories certainly belong to this category of places. In an industrial research lab, scientific research is performed, but for the sake of technological developments. The people working there find themselves in a sort of double role: On the one hand, they want to be serious scientists, who publish in well-respected scientific journals; on the other hand, they are well aware of their position within the totality of the industrial company, where new products and processes must be developed in order to survive financially. Studying the way these people have historically struggled to find a proper position within the company offers a way of understanding these science-technology interactions, some of which have been more successful than others. Naturally, the extent of their success must always be judged against the background of the socioeconomic circumstances of that time.

The next question is: Is there any material available for this sort of study? The answer is: Yes, some material exists and more is being developed. Some of the major industrial research laboratories, such as the famous Bell Labs, General Electric Labs, or the Du Pont Labs-all in the United States-already have their written histories published. Some major industrial research labs are having their history written right now, for example, the Philips Research Labs. For some major industrial labs, such as the Siemans Laboratories, no written history yet exists. Some smaller labs have a written history, too. In this article I mainly draw from the historiographies of larger research labs, since they yield the richest material for the type of analysis I wish to make.

Patterns of Interactions Between Science and Technology

What types of science-technology interactions do we find in the histories of the various industrial research laboratories? In this section I explore three interactions (in chronological order).

Science-and-Technology

The first type of interaction is the almost total integration of the industrial research lab in the overall company. One might describe this complete immersion using the term science-and-technology, as if it were only a single concept rather than two separated by the word and. That is the sort of interaction found in the early history of the companies, when they were still small and their organization was often very informal. In fact, the rise of independent laboratories in such companies is one of the aspects that Chandler (1977) called “the visible hand” in industrial organizations: The management of those companies created a strategic model with distinct functions, such as R&D, production, marketing, and sales. The contacts between people working in the research lab and people working in the rest of the company were based primarily on personal acquaintances. Sometimes these contacts were so direct that it was difficult afterwards to identify exactly where the boundary existed between research activities and product and/or technology development. At the AT&T Labs, it is well known that between WWI and WWII, entire labs were involved in almost all innovation phases (Reich, 1977).

In the case of the Philips Research Labs, we also find similar interactions during this period. Work in the area of X-ray tubes was initiated because of the personal contact between Anton Philips, one of the owners of the company, and Gilles Holst, who was in charge of the lab during that period. Philips was concerned about health care in the Netherlands and the problems of hospitals obtaining adequate X-ray equipment when there was no more deliveries from Germany because of WWI. At first, Holst had some of his researchers repair X-ray equipment from hospitals and simultaneously do research on that equipment. When they started yielding improved and new types of X-ray tubes, such as the Metalix and the Rotalix tubes, a pilot production was started. In the end this resulted in a new business area for the company that still exists today.

In the same way, various new areas emerged and the product range diversified substantially in the years between the two world wars; the research labs continued to function as engines for new options for the factories. This is not to say that the lab always took the first initiative, but the lab certainly played an important role in enabling the company to diversify into new areas. In general, topics in the research program were almost always directly related to products which interested the whole company and some were already in production. Thus, a lot of new topics emerged out of research that was related to light bulbs, originally Philips’ sole product (Blanken, 1992). For example, when research was done on the negative phenomena of gas discharges in light bulbs, the research lab in the end came up with new types of lighting devices based on this phenomenon (gas discharge lamps).

In the GE Labs, a similar development took place that was regarded as a model to be followed by several Philips researchers. In that respect, Wise (1985) mentioned the contacts between GE Labs and Philips scientist Balthasar van der Pol. The extent to which this way of working was good for the company must be judged against the circumstances that were then favorable for such a development. But later, when Philips had to be more selective in the fields in which it wanted to operate, the almost endless diversification became a problem rather than a stimulus. Relying on scientific developments did not yield a good mechanism for selecting areas that were to be counted as “core business.” Here other sorts of considerations have to be made, such as market analyses that certainly did not belong to the competencies of the research labs. The GE Labs had a similar function for its “mother” company (Reich, 1985). Here, too, the lab played an important role in the product diversification of the company.

In summary: A situation in which the activities of the research lab are almost indistinguishable from the commercial activities of the factories (and later on from the product divisions) allowed the company to enter new areas of products and technologies. This, however, did not yield an efficient mechanism for selecting those areas in which the company wanted to really become competitive.

The Industrial Research Lab as an Ivory Tower

Perhaps this is the popular image of any industrial research lab: a place where scientists of a high level are allowed to do scientific research based entirely on their own interests without any conscious concern for what the rest of the company might ask for. This image is fed by stories of inventive individuals who have come up with wonderful ideas for new products and technologies without a request from any business group or product division. It is the genius of these individuals that results in good ideas and not a specific “market pull”— as we would call it today.

Industrial research labs did function this way, particularly in the 1950s and 1960s. It was stimulated by a strong belief in the importance of fundamental scientific research. This belief was expressed in a well-known report by President Roosevelt’s scientific advisor, Vannevar Bush, entitled “Science, the Endless Frontier.” Bush showed that WWII had yielded many opportunities for new technologies by developing and exploiting new knowledge of the fundamentals of nature. Here we have to be a bit careful with the use of the word fundamental in this discussion. Fundamental often means a concern with the basic structures of matter, but here the same term concerns the phenomena underlying the functioning of products. For Bush, the first type of fundamental research was very important. His report was one of the reasons several industrial research labs enhanced their fundamental research capacity. This was an important stimulus for the emergence of science-based industrial developments (Noble, 1979).

In the Bell Labs, for example, it stimulated the study of solid-state physics. This most certainly was one of the main reasons the transistor was invented by Bell Labs. First efforts to design this new device on the basis of trial and error (and the use of analogies with triodes) did not result in a well-understood and reproducible device, even though it did yield the so-called point-contact transistor that could amplify an electrical current. However, the real breakthrough did not come until knowledge of solid-state physics was applied to this problem (Sarlemijn, 1993). This resulted in a device that has certainly become one of the most important innovations in the 20th century.

Equivalent evidences for the success for such an approach can be found in the history of the Philips Research Laboratory. After WWI, the Philips Research Labs found itself to be an autonomous lab in the midst of autonomous product divisions (Blanken, 1998). That caused a variety of transfer problems (de Vries, 1999), as we will also see later. Favorable economic circumstances allowed for a great deal of free research, whereby the lab did not suffer from the problems of its main European competitor, the Siemens Labs, where researchers’ work in certain areas was forbidden by the Americans (Pfisterer, 1987; Trendelenburg, 1975). It also allowed for a great deal of new research in which quantum mechanics played an important role. In that respect, it was quite suitable that the research representative in the Philips Board of Management, Dr. Hendrik Casimir, was a well-respected physicist who himself had contributed to the development of this new scientific theory (Casimir, 1983).

In the case of the Philips Research Labs we can point to the invention of the so-called Plumbicon, a television pickup tube that is still used in professional cameras. It was developed mainly due to the use of solid-state physics as a selection mechanism for optional target materials that would have the necessary photoconductive properties (Sarlemijn & de Vries,1992). But the same example shows the problems of such an approach. The research lab in this case had great difficulties in transferring the device to the product division. Even though the lab had succeeded in making prototypes of the pickup tube, the production of larger quantities appeared to be quite problematic. Mass production is not really an appropriate term here, given the limited numbers of pickup tubes that were needed to supply the broadcasting companies. And here it was not so much fundamental research that helped to solve the problem, but a good engineer’s fingerspitzengefühl (intuitive knowledge by experience). Although at first glance the Plumbicon seems to be an example of applied science, the same case study undermines this paradigm as we look further into its development.

When we look into the history of the Philips Research Labs, and we count the number of successful innovations that emerged in this way from the research labs in the 1950s and 1960s, we only find two important innovations: the Plumbicon and LOCOS. LOCOS stands for LOCal Oxidation of Silicon. This technology is used to produce integrated circuits, which for a long time was the dominant technology for all IC producing companies. Thus it yielded enormous license incomes to Philips and ranks as one of the greatest successes of the company. These two major innovations in a 20-year period counterbalanced a lot of research outcomes that never became successful.

The research program was very expansive in that period. It became evident that this way of working was no longer suitable when the amount of effort spent on research is reduced while the rate of successes remains the same. Only one or perhaps even no big success at all came out of all of this. Of course, such a result can not be afforded by a company for very long.

There are case studies that show how costly non-hits can be using this ivory tower strategy. In the first place, we can point to the video disc. Both Philips and RCA Labs worked on this optical recording system. In the RCA Labs it was seen as an important project through which the lab could regain its status as an innovation center for the company following a difficult period of personnel reduction after the lab had made a wrong strategic decision in computer research (Graham, 1986). Like the Philips Research Labs, the RCA Labs functioned as an autonomous lab in the midst of a number of autonomous product divisions. A choice was made to elaborate the optical storage technology, even though some other options had been tried and not yet completely rejected (e.g., Photopix with small pictures on a disc and Discpix with capacitive storage of video information).

A large market was expected even though there was no hard evidence for that. And when-after many years of intensive research-a working product finally could be delivered, the market that the lab had expected appeared to be nonexistent; only small numbers of video discs were sold. The Philips Research Labs went through a similar process, but they could afterwards claim that the same optical recording knowledge that had been gained in the video disc project later on could be used to develop the compact disc, unquestionably a successful product, in a relatively short time. However, the development of the compact disc was not an example of an ivory tower process, but of the sort of process that will be described earlier.

For the Philips Research Labs there is another famous example of ivory tower research with failing commercial results: the hot air engine, or Stirling engine (de Vries, 1993; more detailed information can be found in Gradstein & Casimir, 1966). Due to the high degree of freedom for the researchers, this project was continued for many years even though not a single product division showed any interest in the engine. Finally, in 1979, the project was stopped after more than 40 years of research. It is evident that this sort of failure is inevitably a risky aspect of an ivory tower industrial research situation.

Customer-Oriented Science

In the 1970s most industrial companies had to redirect their research programs because of changing socioeconomic circumstances. In the first place, a lot of criticism against the place of technology in society emerged. At the same time, economic growth diminished and customers became more selective. It was no longer true that any new product would naturally find a substantial group of buyers. Industrial companies had to be more selective in putting new products into the market. Thus a company's business or product division influenced the research programs.

This process can be seen not only in the history of the Philips Research Labs, but also in the history of the Bell Labs, the General Electric Labs, and the Du Pont Labs. In fact, Philips was one of the slowest to make such a transition because it kept its research program structured according to disciplines rather than products (the three main groups in the Philips Research program remained: materials (mainly with chemists), devices (mainly with physicists), and systems (mainly with electrical engineers). Most other labs changed the structure of the research program to enable a better match with the product-oriented structure of the rest of the company (for Du Pont, see Hounshell & Smith, 1988).

For most research labs, this change soon meant that they had to approach product divisions within their company to get contracts for them. This was another process that was postponed until the 1990s in the Philips Research Labs, but in the end was forced upon them too by the company's Board of Management (van Gruijthuijsen & Junge, 1992). One of the major struggles in this process was to find a balance between freedom for the lab, which would enable researchers to keep doing long-term research, and mutual commitment between the research lab and the product division. Lack of this commitment, in the case of the Philips Research Labs, had frustrated a fruitful customer orientation (the customer being the product divisions of the company) in the 1970s and 1980s. Even though a lot of formal contacts were established between the research labs and the product divisions, often the cooperation did not end with a useful product, but instead could be easily broken off by either of the two parties. It was only the introduction of contract research and a new way of financing the research program (no longer by a lump sum directly from the Board of Management, but to a large extent from the budgets of the product divisions for targeted research, through which the product division was to define the targets) that brought a solution to this serious problem.

When we look at the outcomes of these changes, we see that the research labs no longer yield many dramatic breakthrough innovations, but numerous smaller contributions to product developments. The lab serves as a continuous source of know-how in a variety of quite different areas. One of the major successes of the Philips company that resulted from this type of science-technology interaction is the compact disc. Contrary to the Plumbicon, this idea did not come from the research lab but from one of the product divisions. But its development required know-how from very different areas, such as optical recording, signal processing, and IC design and technology. All these know-how areas were present in the lab; thus a combination of these different areas could be used to achieve the desired product (Ketteringham & Nayak, 1986; Lang, 1996). In fact, a lot of this expertise was gained in the development of a product that is still an example of the previous way of working (in which the lab served as an ivory tower), namely, the video disc (for example, the RCA video disc as an example of ivory tower behavior). Commercially the video disc never became successful, but it resulted in the knowledge that later would be used to support the development of the compact disc (certainly a major success for Philips).

Science in Technology Education

We have seen three types of science-technology interaction by studying the history of industrial research laboratories:

1. A very direct relationship, whereby the two are almost integrated and science serves as a pushing force.
2. A situation in which the two are quite distinct and technology is the result of selecting and elaborating ideas that emerge from scientific research.
3. A situation in which scientific research is done on demand by technological developments.

All of these approaches are successful in a way, and each has also caused problems. The science-and-technology situation enabled smooth transfer of ideas but did not provide good selection mechanisms for technological developments. Fortunately in the years when most industrial labs worked according to this type of interaction, this was not a problem because of the social and economic circumstances. The ivory tower strategy yielded a number of real breakthrough successes but was often accompanied by difficult transfer processes. Also, this was not really a problem because the company could afford a great number of non-hits. The customer- oriented research strategy resulted in a constant flow of knowledge that enabled incremental, rather than breakthrough, product developments.

In a way these categories seem to be not so far away from Layton's cathedral, quarry, and store roles of science education (Layton, 1993), which were derived from a methodological rather than a historical approach. But some differences exist. The role of science as "cathedral" for technology, in Layton's terms, means that fundamental science is performed and technology can study it to learn research methods. "Quarry" means that technologists take from science what they think is useful and leave the rest alone. Finally, "company store" is meant to explain the way that scientists take into account the needs of technologists when developing and presenting their studies. What we have seen in the history of the industrial research labs is a cathedral and quarry role in Section 2.2 and a company store in 2.3. What seems to be missing in Layton's analogy is a role as described in 2.1, whereby the work of scientists and the work of technologists are so closely related that they almost seem to be integrated.

What can we learn about the way scientific knowledge and science education can interact with technology education (because that was the original question that triggered us to make our historical comparisons)? Primarily it is important that pupils become aware of the different roles science can play in technology. Often technology education curricula do not seem to differentiate clearly enough between different types of technology. The focus is often on what is common in all technological developments. This serves as an effective basis, but we should make clear that all the commonalities do diminish the notion that one technology is not necessarily the same as another. One of the aspects that differentiates them is the role of science.

One way of considering this differentiation in technology education is by doing what we did in this article: reviewing the way different products were developed in different periods of the history of industrial research laboratories. Historical insights should be part of technology education anyway; we can make them fruitful by using them to illustrate the difference between various types of science-technology interactions.

But there is more. As we have seen, the different science-technology relationships all have their strengths and weaknesses. In technology education we should build relationships with science education in such a way that we enhance the strengths and avoid the weaknesses. Let us look again at the three interaction patterns we have seen.

A "Science-and-Technology" Pattern in the Curriculum

The science-and-technology pattern would have as its educational equivalent the integration of science education and technology education. As in the industrial research laboratories, this will probably result in science being the main driving force behind technology. Those technologies will be dealt with in the curriculum where scientific research played an important role. Such an approach will result in a great variety of possible issues (as in the industrial company a variety of new industrial activities emerged out of this science-technology cooperation). But it may not provide a useful selection mechanism to help us find those issues that are really relevant for the "market," that is, our pupils. What do they really need in their future life in a high-tech world? Such information is not necessarily taught when science defines what is worth integrating in the curriculum and what can be left out. Thus we can conclude that this option can only be successful if we have many teaching hours available since the number of issues that must be dealt with is very large. There must be time to cover at least a number of topics that are relevant for the pupils from a social perspective. Just as we saw in the science-and-technology pattern, it did well in a time when many new products could be developed in an almost risk-free atmosphere because there would always be enough output to generate revenue.

An Ivory Tower Pattern in the Curriculum

The ivory tower pattern has its educational analogy in science education and technology education when they are separate and do not communicate with each other, but technology education selects certain issues from science education (a company store role of science education) and learns the lesson that concept teaching, which is the key issue in science education, is important (a cathedral role of science education). The history of industrial research labs suggests that this will result in breakthroughs for technology. That may hold when we make the comparison with education: It would be a major step forward if we were able to build up a technology education curriculum that-from a conceptual point of view-is as strong as the science education curriculum. Likewise, the understanding of technology would be greatly enriched if we would show pupils how sophisticated use is made of natural phenomena. But we should certainly be aware of the pitfalls of this pattern: The transfer from science to technology can be most problematic in this case. It requires a very good professional relationship between science teachers and technology teachers if this is to work out well.

A Customer-Oriented Science Pattern in the Curriculum

Finally, we have the option of the customer-oriented science pattern. Here science will adapt to the needs of technology. A skeptic might say that a miracle has to occur if this is to become practice in schools. In the history of industrial research labs, we have seen that it only became a reality because it was forced upon the labs by the higher management of their respective companies. The same might be true in education: We can hardly expect that this well-respected and established school subject will adapt to the "newcomer," technology education. Yet, the history of industrial research labs shows us that, particularly when time and resources become scarce, this interaction pattern could be quite fruitful. Of course some opportunities for science/science education for its own sake should remain, but a substantial part could serve effectively as an input for technology/technology education when it is developed and presented in such a way that it can easily be absorbed by technology. The history of industrial research labs shows us that two elements are needed for this to occur:

1. Mutual commitment: Science education should commit itself to provide relevant input for technology education and technology education should commit itself to make use of this input.
2. Shared project work: Science education and technology education should work together in order to understand each other and to be effective in their relationship.

When these two conditions are fulfilled, the customer-oriented science pattern will prove to be as fruitful as it did in the industrial labs situation. It may require a lot of effort before we get there, but as long as time and resources are limited it is worth pursuing this approach. In the end both science education and technology education would benefit from these collaborations and commitments.

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A Critical Appraisal of Learning Technology Using Information and Communication Technologies

George Shield

Introduction

The government of the United Kingdom is currently reaffirming its promise to link every school, college, university, and public library in the country to the “national grid for learning” at a cost in excess of £100 million (Howells, 1998). These links will be free, and access to all who require it guaranteed. Every child will have his or her own e-mail address to access learning resources worldwide. As well as this access, the Prime Minister is ‘online’ so that the public can pose questions electronically and, presumably, expect a reply.

This type of initiative together with the exponential increase in the availability of information and communications technologies (ICT) has created opportunities for teachers to exploit a new tool. However, the research base for exploiting these new tools, as well as examples of good professional practice, is in its infancy and still requires considerable thought and empirical investigation (Barnard, 1998).

Context

In the world of education the burgeoning in the availability of ICT has created exciting opportunities for its exploitation. However, ICT, like all new tools, provides a challenge to established thinking. The attractiveness of ICT to education is a two-edged sword. While it may lead to the provision of additional resources for education, it also leads to expectations that are often problematic to deliver (Bottino, Forcheri, & Molfino, 1998). The educational advantages claimed for ICT are often not translated into meaningful learning activity (Barnard, 1998), particularly in the specialized field of what can be termed school technology, and it is important, therefore, that these advantages are identified and justified by practitioners as well as being explained through learning theory. Technological developments occur in two ways: (a) as a solution to a known problem or (b) as a spin-off from other research and a search is made to find uses for them; technology becomes available and then opportunities are sought to employ its potential in the classroom. This approach is not the most appropriate strategy; it is frequently ineffective and sometimes leads to the early discarding of a potentially useful tool. The reasons for this vary. It could be that technologies have not been sufficiently developed and that they are being used before teething problems have been rectified. Or it may be that they are too “sophisticated” for the job at hand. In other words, the teaching and learning strategies may be over-engineered and busy teachers have no time to de-bug software or persevere with inefficient approaches.

It is, therefore, essential that as well as providing a new tool we should try to explain its application within current learning theories (Wild & Quinn, 1998) so that we are using it from a position of authority, based upon a sound knowledge base, and not relying upon serendipity. In other words, the design and manufacture of learning materials, particularly when utilizing new technologies, should be purpose built and not be media led (Dyne, Taylor, & Boulton-Lewis, 1994).

And within technology education we have even more particular issues to address. Technology within the context of education can be described and defined in several ways. For many it has to do with using technology to enhance the efficiency of the educational process. Within this context is the use of the personal computer and all that goes with it: its use as a word processor, highly efficient calculator, database, and communication system. In other words, the personal computer becomes a library and access system to the world's store of knowledge as well as a manipulator of that knowledge.

A slightly different justification for technology education is the understanding that one can acquire knowledge of a range of other subjects through the study of technology. For example, by building a model bridge in cardboard or wood or even modeling it on a personal computer, learners will apply mathematical skills and understand scientific concepts through their application (McCormick & Murphy, 1998). Some would take this argument further and claim that other more ephemeral attributes such as communication skills are gained through technologists explaining their solutions to others, and ethical and moral problems are confronted by debating controversial issues.

While these two descriptions of the value of technology education are both valid and widely held, the most common view is that technology education should be about the acquisition of a thorough grounding in technological principles. This understanding of the activity features prominently in the curriculum of schools through the requirements of the National Curriculum in the United Kingdom and similar directives and recommendations in other countries (e.g., Botswana Ministry of Education, 1996; International Technology Education Association (ITEA), 1997). While the other considerations, those of "learning through technology" are more general imperatives, they are rarely addressed as prime objectives by technology teachers.

If we look at technology education as being concerned with learning about technology, there are said to be three components: skills, knowledge, and values (Assessment of Performance Unit [APU], 1981).

In the United Kingdom, these technological understandings and accomplishments are said to be acquired through the processes of designing and making. The subject is essentially one concerned with practical action and capability (National Curriculum Council [NCC], 1990) although some of the content is acquired through focused tasks designed to facilitate problem-solving capability through the development of specific skills and knowledge. It is within this

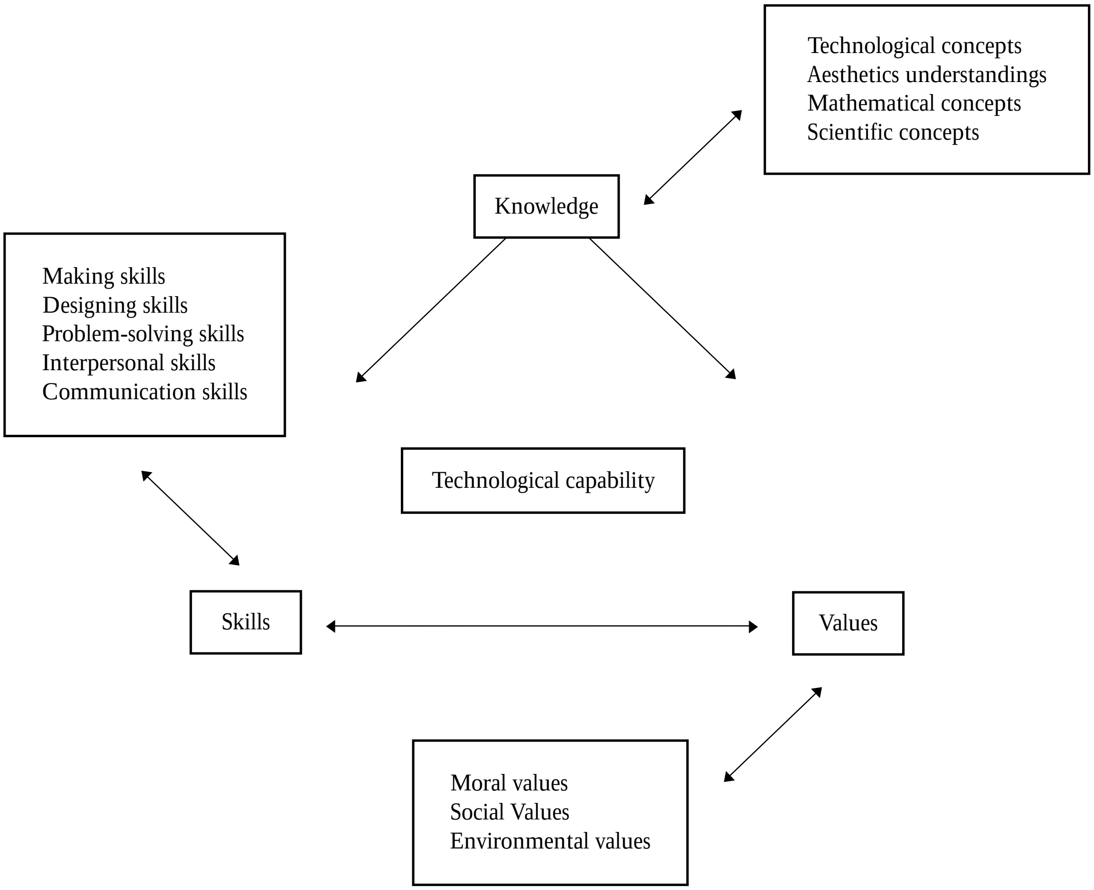


Figure 1. The interrelationship between skills, knowledge, and values in technological capability.

broad definition that this article was written.

While it should be remembered that a number of other curriculum subject areas also lay claim to a wide range of desirable attributes with problem solving, social awareness, and knowledge acquisition featuring prominently in their aims and objectives, technology education is perhaps unique in that the results of such problem-solving activity is often translated into tangible artifacts or solutions.

A further factor to note is that such practical activity is not necessarily employed to explain a scientific concept or justify an aesthetic principle, but one that constructs the technological reality of schoolroom learning. It transforms scientific experiments with string and meter rules into machines found on building sites or dockyards and applies the aesthetic principles used in art studios to the creation of functional and attractive artifacts. Involvement in designing and making activities thus enables a number of technological concepts to be established or existing ones enhanced.

This demand may be said to require of teachers and learners in the subject area a much wider range of skills (both professional and pedagogical) than are often expected elsewhere in the curriculum.

Learning and Teaching

Education is seen, certainly at its higher levels, to be concerned with developing the ability to explain and predict the outcomes of innovative situations as they occur (Wild & Quinn, 1998). This ability is necessary to solve problems and comes from a combination of experiential and academic learning and is acquired through the skill of being able to make appropriate judgments based on personal reflection.
Another common definition of learning, which stems from behaviorist theory, is that learning takes place when a relatively permanent change in behavior occurs. This definition takes the word behavior to mean any observable change that takes place. In other words, if someone can now do something (e.g., remember a fact, demonstrate a skill, perform an operation) that he or she couldn't do before, it is said that learning has taken place. Behaviorism underpins much learning that takes place formally and informally and has also led to a great deal of current educational practice in assessment and evaluation. Constructivists attempt to explain the principles of learning by encompassing the understanding that knowledge is constructed by the learner in the context of his or her environment. It is therefore acquired when the learner actively tries to make sense of new experiences based upon his or her previous understanding (Bruner, 1972).

Sociocultural theories rely heavily upon the value of communication in the learning process (Meadows, 1998). This can be between teacher and learner in the formal sense, but it may also be between peers and others that occurs within a normal social context. Language is therefore extremely important to allow for successful interaction and, hence, learning to take place. The principles behind scaffolding and the zone of proximal development (ZPD) fall within these theories (Gredler, 1992; Kincheloe & Steinberg, 1993; Tharp & Gallimore, 1988).

These more complex theories of learning do not totally exclude behaviorist theories that propose the independence of knowledge from social and cultural influences, as such instrumental approaches are useful for understanding the basis of some teaching strategies, particularly those concerned with lower level skills (Atkins, 1993).

Figure 2. Cognitive Theory and Computer Use, McLaughlin and Oliver, 1998. p.128

Theory	Behavior	Constructivist	Socio-cultural
Activities	Drill and practice tutorials	LOGO programming Micro worlds	Collaborative learning
Learning Process	Individual instructions and feedback drill and practice	Individual, discovery based generalisable skills	Social scaffolding interactive, reflective

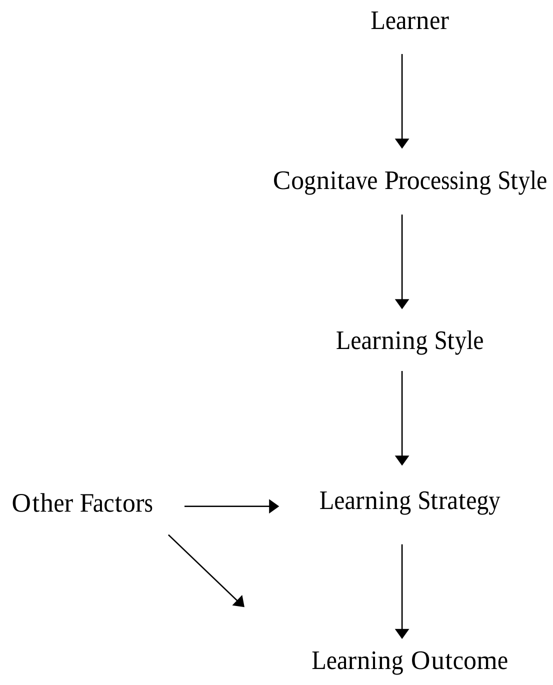
Examples of these theories of learning and their application provided by McLoughlin and Oliver (1998). These theories are very rarely used independently of each other to explain learning: Most skilled teachers are simply adept at knowing when and where to employ them, often subconsciously, to produce the most effective results.

Strategies based upon behaviorism can be used effectively for factual and rote learning, and teachers use this theory frequently by rewarding a learner with encouragement or other more tangible signs of approval. Such basic learning theories are also often used in programmed learning where a student is rewarded through an encouraging comment before moving on to the next learning objective.

It is in this type of learning that the use of ICT is immediately apparent. The computer games that are so highly addictive to teenagers are perfect examples of learning behavior being progressively rewarded as each level of the game is mastered. This learning is not restricted to the cognitive field in which the game is mastered but also in the area of psychomotor skills when the reflexes of learners are constantly refined to produce ever faster reactions to visual stimuli.

The student's mastering of basic technological terms, descriptions of components, and understanding of theory behind technical processes can be achieved through structured programs delivered through CD-ROMs or similar media. We can, therefore immediately see a place for ICT in technology education, both as a source of information and also, if structured effectively, a context or structure for learning simple skills and concepts.

Figure 3. Learner characteristics that affect learning.



Obviously, such teaching and learning strategies are not sufficient for all learning. They are, however, often needed at some time to service processes that will enable learners to acquire basic information to undertake higher order activities including problem solving (Atkins, 1993).

Different learning objectives may require different teaching and learning strategies to achieve them. Some aspects of learning require basic low-level information as a preliminary activity before the more complex can be internalized. Often the rote learning of factual information is essential before a learner can be engaged in problem solving or those higher order activities deemed more desirable (Underwood & Underwood, 1990). While behaviorism is said to have a number of views, this view of learning drives a lot of current educational practice where competencies and standards have become established indicators of achievement.

Thus, in technology education we have a subject that inherently has a philosophy that is overlaid by effective learning theories. By the very nature of students being involved in design and make tasks, they are learning through real-life contexts and strategies that in many other school subjects have to be artificially created. Therefore, we must think carefully before we change a learning experience, which can provide a worthwhile education in its own right.

The links between teacher and taught are of crucial importance. Satisfactory learning often takes place when the teacher identifies where the learning blockage occurs. In other words, by determining where the difficulty is occurring in the student, the teacher can rectify the wrong concept or build upon work already understood. Based upon this understanding, Andaloro and Bellomonte (1998) suggested that a way forward is to use the computer to model the student's learning strategies to signify where they are likely to encounter difficulties in the future and thereby build up a learning program for each student, ensuring that the ICT programmers' emphasis recognizes that learners are different in the learning strategies they employ and the material is adapted accordingly. This activity can be used as a precursor to the use of design packages and simulations. Much is currently being made of the use of computer-aided design and simulation packages to aid student problem solving, but without an understanding of the learning profile of the child (which the good teacher uses in traditional contexts), most of this activity may not be used to its best advantage and is directed to task achievement rather than the development of a learning skill (i.e., they may assist a student to design a specific product but not necessarily teach that student how to develop design skills).

Learning is a personal activity. It depends upon a series of factors that are often very difficult to control and manipulate. Some of these factors are related to the individual, including cognitive processing style and learning style. Some people learn better within a group situation; others by reading the printed word. Some learn through graphic symbols (Thompson, 1990); others through instruction. Other factors include the learning strategy employed (often controlled by the teacher) and the expected outcomes. Lord (1998) illustrated this view in diagrammatic form:

A number of learning tasks can be readily aided through the routine use of ICT. Simple skill acquisition, knowledge building, and modeling through simulations can give practice to aid creative development. However, when the tasks are related more to higher cognitive tasks, the benefits become more problematic. Passey (1998) suggested that in developing higher order skills, ICT has a more restricted role than with work in lower order domains, with the concomitant suggestion that work in the higher domains requires more in the way of teacher intervention. The continuum lies between the teacher being assisted by the technology and the teacher teaching to the technology.

Most learning theories have much in common, such as the need for motivation and consideration of individual differences in learners. Students are not all interested in the same topic, do not have the same physical or psychological characteristics, and do not come from the same environment. These individual differences are clearly evident in design and technology and particularly in their design project work (Atkinson, 1998; Wu, Custer, & Dyrenfurth, 1996). This would indicate that the most effective way forward would be an individualized learning program for each student where the acquisition of knowledge, skills, and values could be tailored to each student's special needs. This student-centered approach in technology education, sometimes called the investigative learning approach (Sellwood, 1991), creates heavy demands on the teacher and, consequently, it is often modified to ensure that it is manageable within the classroom context. The resulting curriculum and its implementation is a compromise between the resources available and what is required by the student (Barlex, 1993). This concept of individualized and differentiated learning as an ideal methodology has strong advocates and yet is not very common in school (Thomas, 1992) because teachers, understandably, find it difficult to determine and meet the needs of both the better able and those with learning difficulties. They also find this methodology time consuming when working under pressure to transmit facts and achieve observable changes in behavior (Kyriacou, 1992) such as design folios or technological reports and records for assessment purposes.

Some teachers have already recognized the use of a personal computer can facilitate individualized learning, particularly as a source of information. The provision of information is, of course, not sufficient for learning to take place as it does not necessarily lead to understanding. For example, the importance of cultural and social interaction is stressed by Bruner (Wood, 1988) as necessary for cognition (Jenkins, 1994). (Technology teachers often take advantage of this understanding and build such work into their programs. Hill and Smith [1998] described a program of manufacturing technology education in which they base the work on community needs specifically to harness this student involvement with others.) However, the additional dimension of the individual's cognitive makeup (Salomon, 1991) is also important in the development of technological concepts. It is this combination that forms the basis of individuality that could explain the value of ICT with some learners and yet totally fail to connect with others. The social interaction that is essential to many learners may take a unique form with others. It is possible that the interaction becomes one step removed so that the relationship is at second hand and is mediated through the technological hardware. McLoughlin and Oliver (1998) demonstrated that students working in groups using personal computers interact in such ways that cognitive abilities and concepts are developed much like face-to-face interactions. The interaction between learners using the Internet could be as valid as the interaction between teacher and learner in a traditional setting. In an

Australian study, Williams and Williams (1997) recognized the validity of this interaction and also identified some practical problems when engaged in collaborative designing using remote interaction. Clayden, Desforges, Mills, and Rawson (1994) elaborated upon the view that learning is a product of negotiation, a constant initiation into socially constructed webs of beliefs, thus requiring much more than the transmission of knowledge. This socially constructed web, however, may not necessitate a physical presence. It is the quality of the interaction that is important, not the means of exchange.

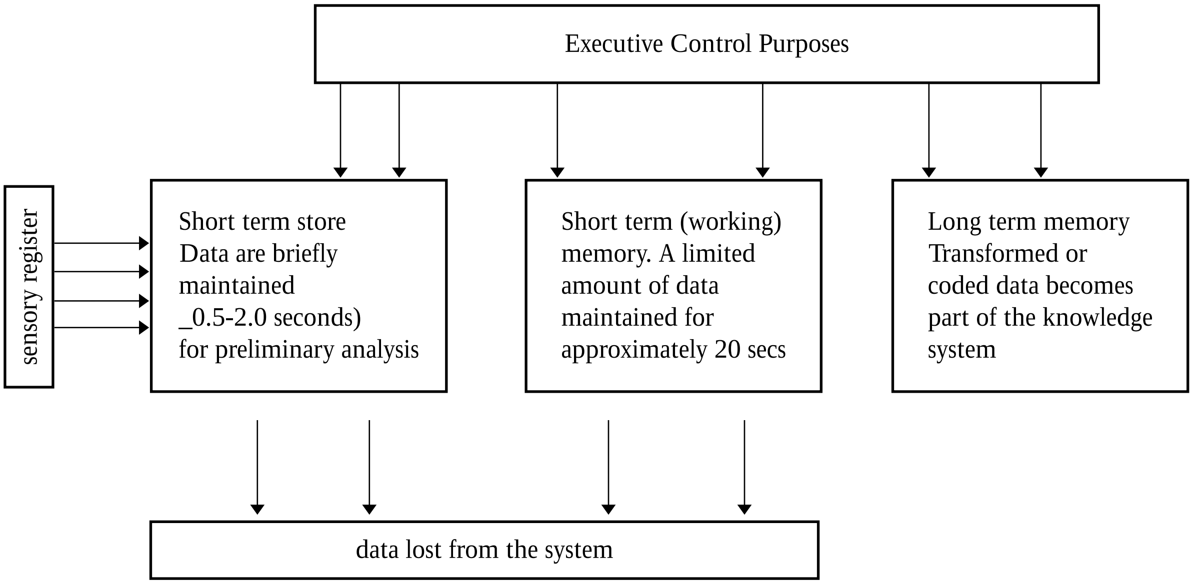
One Way Forward

One way forward is to switch our attention from the design of software packages (which act solely as storehouses of information) to an interactive problem-based environment in which the student assumes the key. Currently, where it is common practice to produce learning materials that are uniform for all learners the learners must “fit in” with the suggested activities. The learner should not have to adjust to the equipment available; the learning task should always be the dominant factor (Beardon, Malmborg, & Yazdani, 1998) and the software designed to this end. In this model, the first task of the learning package is to develop a picture of both the student’s learning strategies as well as an analysis of the student’s existing knowledge and cultural base (Tweddle, 1998). With this profile in place, the learning task can be tailored to the student’s capabilities rather than the student having to fit in with the software designer’s generalized understanding of how learning should take place (Andaloro & Bellomonte, 1998). The creation of these rich learning environments will also have to ensure that texts, reference sources, multimedia, and communication facilities are fully integrated.

While it can be seen that major benefits can accrue from the use of ICT in technology education, it will not be sufficient on its own to provide a meaningful program of learning activities that can deliver the full range of desired outcomes. Technology education as it is practiced in schools is essentially a practical activity and the making element is fundamental to the learning activity. Other theoretical models must be identified to explain the shortcomings.

What appears to be a fundamental difficulty in the utilization of ICT in this subject area is the basic belief that in technology we are involved in education through the use of materials (i.e., if the connection is broken between the content and the process through which it takes place, the subject’s raison d’etre is nullified). A computer simulation cannot be used as a substitute. Baird (1990) used the concept of metacognition to explain this differential understanding. He claimed that metacognition can be enhanced through both the content of what is to be learned and also the context in which it is to be

Figure 4. Information Processing (Gredler, 1992)



learned. The reason for this understanding can be illustrated through an information processing model of learning shown in Figure 4. While such models are hypothetical, they provide a valuable insight into the value of technology education as a process as well as a body of knowledge.

These theories are derived from models in which data, developed from perceptual cues, are processed in a logical fashion to provide desired outcomes through the systematic ordering and restructuring of new information. In information processing models of learning, information is received through our sensory organs where some of it is lost and some of it is filtered for its importance before being passed to the short-term memory store. (When working in a workshop or studio, the range of senses employed by the learner is increased. The tactile and olfactory senses employed when working with resistant materials together with sounds generated must all help to build more accurate concepts than those obtained from working solely with the printed word or even a computer simulation). At this stage, information is consciously worked upon and sometimes used for routine operations. Data or information that is recognized to be of greater value is subjected to transformation and transferred to the long-term store for appropriate concepts that "make sense'" and for use when needed.

This is obviously a very complex process that relies upon the accuracy of the interpretation of the perceptual cues that are received from our sensory organs and also the ability of the brain to recognize appropriate schemata or connections. The learning process can therefore be enhanced if the learner uses a range of sense organs (Eisner, 1985) to help form the concepts under development. The wider the range and the more accurate the inputs, the more effective the learning is.

While information processing models of learning are useful in explaining how changes in behavior in the cognitive domain may occur, these theories are not solely concerned with that domain because the sensorimotor skills necessary for the implementation of much technological/scientific/physical activity are said to have much in common with the mental skills used in categorizing and processing knowledge for other forms of activity (Welford, 1971). We could, therefore, have an understanding that encompasses and explains a lot of activities found in technology education. Again, it is important to stress that while an information processing model is of value, it cannot be the whole story. Dyne et al. (1994) suggested that information processing explains in part the learning that takes place while acknowledging that what they term "student approaches to learning" (SAL) as an essential component. Learning occurs both within the student as well as within the teaching\learning context.

Conclusion

We are often confused by the virtues of ICT. Its advantages for data retrieval and routine, lower order activities are obvious and often valuable. However, the application of ICT to technological problem solving or other higher level research activities still leaves much work to be done.

In summary, there appears to be at least five stages or levels in the use of ICT in technology education:

- Level 1 is the development of routine skills such as word processing or graphics packages as an aid to clarification and communication.
- Level 2 is the use of ICT to search databases such as CD-ROMs and the WWW as a powerful library. It is important to realize, however, that it is not sufficient to give students practice in using such sources; they also require skills in finding the information and in discrimination of the results.
- The third level is the adoption of existing programs to gain a deeper understanding of the power of ICT to "number crunch," to control mechanisms, or for modeling simple solutions to attainable problems.
- In Level 4 the learner moves from the direction and guidance of the teacher to the development of creative thought, possibly not until senior levels of school or university education. The PC now becomes an extension of the brain.
- The fifth and possibly most difficult level to attain-and the one in which most research needs to be done-is related to the development of understanding of the cognitive processes of the learner and the application of this knowledge to specific tasks. At this stage we may be able to develop generic creative abilities rather than the ability to understand specific problems. When we can utilize this capability, we will begin to be able to exploit the power of ICT in the learning environment.
- While it is obvious ICT can be used to aid learning, the real breakthrough will occur when truly interactive packages provide rich learning environments.

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