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Contents

From the Editor

The JTE: Retrospect/Prospect

The first issue of the *Journal of Technology Education* made it's way to the profession in the fall of 1989. Five years/volumes later, it seems appropriate to reflect on its brief history and future potential. From the onset, the JTE has been a modest venture, a stature pretty much assured by its focused scope. The Editorial Board has steadfastly promoted research and publication relating to the teaching *about* technology, the tradition begun perhaps with William E. Warner's "Curriculum to Reflect Technology" in 1947. The Journal has consistently turned away manuscripts that do not somehow relate rather directly to technology education.

While specific in scope, the JTE has drawn contributions from researchers throughout the world who are wrestling with many of the same issues that confront us here in the States. Articles describing technology education in the Netherlands, the United Kingdom, Canada, the People's Republic of China, Japan, and Australia have been published in the JTE. Contributions from leaders in Science, Technology, and Society have also appeared regularly in the *Journal*. And JTE readers in dozens of countries attest to the interest worldwide in the research of the profession.

The JTE Editorial Board has given generously of their time to review scores of manuscripts for publication consideration each year. They have attended to this task with great professionalism, providing encouragement and constructive feedback to all authors who submit to the *Journal*. At the same time, authors have been forthcoming with their manuscripts and understanding of the rigorous review process that the JTE employs. Prospective authors have been universal in their praise of the work of the reviewers, whose primary task is to recommend ways in which manuscripts may be strengthened. Working with authors in this respect has been a primary role for the JTE. Similarly, regular presentations on writing for the JTE at the annual ITEA conference have helped to bring prospective authors along in the process.

One of the most significant developments in the publication of the JTE during its first five years has been the advent of the electronic version (E-JTE). In the Spring of 1992, the E-JTE became one of the first handful of refereed professional journals in history to enjoy worldwide electronic distribution via the Internet. As I reported in Volume 5, #2, that venture has progressed far beyond original expectations. Thousands of individuals from all over the world now routinely download articles published in the JTE. Our ideas and issues are being read by many who have previously had no understanding of our profession or the task that challenges us–teaching young people about the technological world in which we live.

It isn't surprising to me that research, in the traditional sense, is relatively sparse in technology education. Our profession is rich with very capable and creative individuals who have focused more on *doing* than on *reflecting* and *reporting* the results of this developmental work. As a result, our teachers, instructional methods, and curriculum models are among the very finest in education. They represent a brand of scholarship that is rarely recognized; the scholarship of transforming theory into practice. The curriculum, methods, and laboratories that gifted technology teachers develop *are* their scholarship; they reflect a unique and effective model of constructivist education. Our laboratories routinely employ the methods other disciplines desperately seek–hands-on problem solving, collaborative learning, authentic assessment, and of course, integration of technology with the curriculum, to name but a few.

My point in all of this is to suggest that we need ways to recognize the particular brand of scholarship represented by those engaged in these developmental activities. Academic journals have been the traditional means of disseminating the ideas of a profession, but print is not a very good medium for showing off the work of creative practitioners in our field. Electronic publication offers us a new opportunity to do just that. Through the World Wide Web, (a hypertext system that enables the dissemination of digital text, graphics, audio, and video across the Internet) for example, we could depict the uniqueness of our curriculum, laboratories, and methods for *all* to *see*. I've considered using the electronic version of the JTE to do this, but this concept is probably too far askance from the relatively traditional JTE to "fit" in that format. Perhaps it would work as an electronic supplement to the JTE?

Whether it occurs through the JTE's electronic version, as an electronic supplement to the JTE, or through another vehicle, our profession *needs* to capitalize on the evolving global information infrastructure as a means of highlighting the "action research" taking place in technology education classrooms. Though we have much to offer, we have thus far not done a good job of communicating our ideas and efforts to those *outside* our profession. The outstanding work taking place in many of our laboratories is visually rich and the World Wide Web represents a potential showplace for our work in this regard.

If you have something you think is appropriate for this format, contact me and we'll talk. If we agree that your material might "work," the JTE stands willing and able to sponsor an electronic "multimedia" supplement to it's more traditional print and electronic formats.

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Articles

In-Service Activities for Technology Education: The Role of Colleges and Universities

Richard A. Boser and Michael K. Daugherty[1]

Many exciting technology education programs are being developed and implemented across the United States. State-wide implementation of technology education has occurred in a number of states such as New York, Illinois, Virginia, and Indiana. Additionally, well publicized regional technology education programs have emerged in locations as diverse as Delta, Colorado, and Pittsburgh, Kansas. These and many other efforts toward implementation of technology education have aroused wide interest in the study of technology and have contributed to the rapid growth of contemporary curriculum materials.

The process of implementing technology education curricula is a complex undertaking that requires an adaptation of philosophy, curriculum, and instructional practices. The dissemination of these new educational ideas and practices is largely contingent upon effective in-service professional development programs (Boser, 1991; Cordeiro, 1986; Wilkinson, 1990). In order for the technology education profession to move forward, practicing teachers of technology education require continually updated information on curriculum, methodology, and technology to allow them to make philosophical and programmatic changes that augment technology education.

Colleges and universities have traditionally facilitated this dissemination process. Further, institutions that provide contemporary pre-service technology teacher education are in a unique position to offer effective professional development programs. University personnel at these institutions are aware of state-of-the-art technology programs and instructional methods. The linkage between the university and practicing teachers is obviously mutually beneficial. Through collaboration, in-service programs may be developed that meet current needs while continually moving the local technology program toward the most contemporary examples of technology education.

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Purpose of the Research

The purpose of this research was to ascertain the extent to which colleges and universities are integrating contemporary technology education curriculum activities into in-service programs. By identifying the degree of involvement and types of technology education in-service activities currently being delivered by colleges and universities, workshop planners in teacher education, state departments, or classrooms, may have a research base from which to design more effective in-service activities.

The following research questions were investigated:

1. To what degree are colleges and universities involved in delivering contemporary technology education in-service activities?
2. What type of in-service activities are offered to teachers by colleges and universities?
3. To what extent are colleges and universities integrating contemporary technology education curriculum activities into teacher in-service programs?
4. What methods are used to deliver technology education in-service activities?

Research on Effective In-service Programs

Colleges and universities have long provided in-service activities for teachers. Richey (1957) observed that teacher educators in "normal schools" were involved in professional development activities in the early 19th century. More recently, research on in-service practices has focused increased attention on its contributions to curriculum change. Guskey (1986) reviewed research on effective schools and singled out quality professional development as an essential component of effective instruction.

Although in-service and staff development activities have begun to be mandated at many local and state levels (Duttweiler, 1988; Mulhern & Buford, 1986), contractual agreements are not usually the primary reason for teachers taking part in the staff development. Guskey (1986) pointed out that even though in-service participation may be contractually required, most teachers seek professional development to improve their classroom performance.

The development of effective in-service programs requires extensive planning, careful delivery, and follow-up of the participant's success in the teaching setting. Lambert (1988) asserted that in-service must do more than give teachers information, demonstrate innovations, and/or provide guided practice. To be effective there must be opportunities for teachers to practice and receive feedback and coaching in the field.

The lack of effective practice, feedback, and coaching in the field has been a major flaw in the in-service model that has been perpetuated by workshop presenters over generations. However, Browne and Keeley (1988) indicated that effective follow-up is a problem often overshadowed by poor presentation planning and methodology. The authors suggested that the lecture method of instruction is an overused presentation method used primarily because of ineffective planning. Browne and Keeley recommended that instead of relying on lectures to convey information teachers need "time to design a plan for how the suggested improvement could be integrated into their classroom" (p. 98).

Guskey (1986) suggested that effective in-services must also provide teachers with knowledge and skills that they perceive as potentially useful in expanding their teaching capabilities. Further, Cordeiro (1986) avowed that effective in-service is predicated on the delivery of immediately useful teaching materials and methods. Cordeiro observed that practitioners look for things that work, and ideas that can be put into practice in the classroom the next day. The author also suggested that workshops that feature theoretical content are often poorly attended.

While Cordeiro (1986) and Guskey (1986) suggested that teachers prefer workshops that focus on the tricks-of-the-trade, there is also need for in-service to address concepts such as philosophy or curriculum development to spur initial program changes. As LaRose (1988) noted, in-service must meet the needs of both teachers and the institution. For institutional or curriculum change to take place, in-service may have to emphasize more than just instructional nuts and bolts.

Finally, some research suggested that effective in-service programs provide teachers with financial support or release time. Lodge (1989) indicated that it is important that teachers receive the monetary, time, professional and social support needed to accomplish the in-service goals. Boser (1991) found that participants in the state-wide implementation of technology education programs in New York and Illinois recommended that teachers be paid for attending in-service programs.

The research reviewed suggests that much is known on how change occurs in education and the role that in-service can play in supporting change. If the implementation of technology education is to increase nationally, one would expect to find the components of effective in-service present in college, university, state, and regional program offerings.

Methodology

A questionnaire was developed, pilot tested, and mailed to selected colleges and universities that graduated five or more technology education teachers in 1991. One of the difficulties of assessing the degree of in-service activity specifically occurring in technology teacher education is the identification of institutions that are actually preparing teachers of "technology education." However, it is not always easy to distinguish between programs that prepare teachers of technology education as opposed to those programs preparing traditional industrial arts teachers. Householder (1992) addressed this problem in a recent survey designed to ascertain the number of graduates of technology education programs available for teaching positions in 1992. As part of the study, Householder identified a population of institutions that specifically prepare teachers of technology education. In order to survey institutions actively involved in technology teacher education and thereby develop a portrait of contemporary in-service activity, institutions selected for inclusion in this study were among those colleges and universities identified by Householder as graduating five or more Technology Education teachers in 1991.

Due to the relatively large size of the sample and the national scope of the study, a mailed questionnaire was selected as the most reliable, valid, economical method of obtaining information (Fink & Kosecoff, 1985). The questionnaire was pilot tested at 15 regional technology teacher preparation institutions. Twelve of the 15 pilot questionnaires were returned and appropriate adjustments and corrections were made to the questionnaire. The revised questionnaire was then mailed to the 50 selected institutions.

Results and Discussion

Of the 50 institutions surveyed, 35 questionnaires were returned. Of these 35 questionnaires returned (70%), three institutions reported no in-service activity in the past year and three questionnaires were returned but not completed. In total, 29 useable questionnaires were returned for a response rate of 58%. Each of these 29 institutions reported sponsorship of at least one in-service activity in the past year.

Responding institutions were located in at least 22 states (one questionnaire could not be identified by state). Due to the fact that few states have more than one institution which met the sample selection requirement of five or more graduates per year in technology education, no attempt was made to sort the data by state. Table 1 lists the number of in-service activities reported by the institutions.

Table 1
Number of In-service Sessions Offered by Responding Institutions (n=29).

In-services Offered	Number of Institutions	Percent of Institutions
1-3	9	31%
4-6	9	31%
7-9	2	7%
≥10	9	31%

Coordination of In-service

Two survey items attempted to determine the degree of involvement colleges and universities have in organizing in-service activities. Specifically, survey items asked, “Who coordinates the in-service program in your state?” and “Who typically leads those workshops?”

Fifty five percent (*n*=16) of responding institutions reported a coordinated program of Technology Education in-service in their state. Program coordination used a variety of formats which often involved a cooperative effort between a State Department of Education and a university or college, and/or the state or professional association (*n*=9). Five institutions reported that a government department was the sole coordinating agency in their state, and in two instances a university was identified as the state coordinating agency. These findings indicate that universities and colleges appeared to be active partners in delivering in-service activities in their states.

University personnel were very active in the leadership of in-service and professional development. As indicated in Table 2, 27 of 29 institutions offered in-service sessions lead by university personnel (93%). Not listed on Table 2 bbut specifically mentioned in the “Other” category were: (a) State Department of Education personnel, (b) university personnel and/or graduate student support, and (c) representatives from various areas of education such as the district superintendent.

Table 2
Leadership of In-service Events (Respondents checked all that applied. Maximum n=29 in any category).

In-service Leader	Number of Institutions	Percent of Institutions
University personnel	27	93%
Classroom teacher	16	55%
Business or industry personnel	9	31%
Consultant	9	31%
Other	3	10%

Type of In-service Activities

To understand the goals of current in-service activity and to determine the degree of change toward new technology education content, respondents were asked to indicate which of the listed elements of change were the focus of their in-service programs. The major focus of in-service activities is reported in Table 3. Technology update sessions (*n*=25) and curriculum development (*n*=24) were the most common focus of in-service programs. Only 14 institutions reported conducting sessions focusing on the philosophy of Technology Education. This may indicate that, in many areas, teachers have an understanding of the philosophy of technology education (usually a first step in the implementation process) and that in-service events can now devote increasing amounts of time to issues such as curriculum implementation.

Table 3
Major Focus of In-service Events. (Respondents checked all that applied. Maximum n=29 in any category.)

Focus of In-service	Number of institutions	Percent of Institutions
Technology update	25	86%
Curriculum development	24	83%
Student learning activities	19	66%
Teaching methods	18	62%
Curriculum integration (Math, Science, & Tech.)	16	55%
Philosophy	14	48%
Other (Classroom research)	4	14%

In-service Topics

The 29 responding institutions collectively reported 74 specific in-service topics that spanned a wide range of contemporary issues in technology education from "action labs" to "using Lego educational products." Consistent with the emphasis noted on technology update in-service activities, the majority of topics were designed to expand teachers knowledge and skills in technological areas. Many of these technology update topics specifically addressed computer applications and operation. In-service topics most often mentioned by the respondents included: robotics (7), Principles of Technology (6), CAD (4), integrated academics or mathematics, science, and technology integration (4), CNC (3), desktop publishing (3).

Selection of In-service Content

Respondents reported that in-service topics were typically selected and planned with teacher involvement. Institutions reported various forms of teacher participation. Specifically mentioned were (a) direct teacher input (n=23), (b) workshop committees (n=6), (c) a district teacher meeting (n=1), and (d) collaboration between university faculty members, school district administrators, and teachers. The second most common approach was to have the content determined by university personnel (n=22). Other sources for the selection of in-service content were state plans (n=9), conceptual framework for technology education (n=3), and grant programs (n=1). The majority of in-service topics are determined by teachers or university personnel and not specifically selected through the guidance of a state plan or conceptual framework.

Instructional Methods

Modeling is a meaningful educational practice, therefore it is important to understand the types of instructional methods used to deliver in-service activities. In keeping with the traditions of technology education, both hands-on activities and demonstrations were frequently mentioned instructional delivery methods. Perhaps reflecting the philosophy of technology education, small group activities were also widely used. The venerable lecture obviously still has a place for delivering information quickly to large groups. Methods that were mentioned under the "Other" category included independent study, practicum, and technical occupational experience. Instructional methods used for the delivery of in-service events are reported in Table 4.

Table 4
Instructional Methods Used at In-service Events. (Respondents checked all that applied. Maximum n=29 in any category.)

Methods	Number of Institutions	Percent of Institutions
Hands-on activities	27	93%
Small groups	25	86%
Demonstration	22	76%
Lecture	18	62%
Seminar	13	45%
Other	6	21%

Scheduling Format

Nineteen institutions (65.5%) reported that in-service credits were required by teachers for continuous certification in their State. In attempting to meet this demand, institutions reported using a number of scheduling formats to deliver in-service programs. By far the most common vehicle used for in-service was summer workshops, which were offered by 93% (*n*=27) of the responding institutions. College credit was reported to be available for summer workshop participants in 66% of institutions. College credit was also available for all continuing education programs (*n*=7), and 87% of in-service events scheduled on weekends. Additional formats reported were: (a) spring conferences, (b) local association meetings, (c) consultation sessions, (d) occupational experiences, and (e) individual independent studies. A listing of the in-service formats is presented in Table 5.

Table 5
Type of In-service Delivery Format Used by Colleges and Universities. (Respondents checked all that applied. Maximum n=29 in any category.)

Type of In-service Delivery Format	Number of Institutions	Offered for Credit
Summer workshop or course	27	18
Teacher in-service/institute day	14	2
Weekend	8	7
After school workshop	9	3
Continuing education	7	7
Other	4	0

Attendance

Nineteen of the 29 institutions estimated average attendance at workshops to be in the range of 11-20 participants. Another seven institutions estimated attendance between 21-30 participants. Of the remaining three institutions, one reported less than 10 participants, while the two counted more than 30 teachers in attendance at workshops. Average attendance was 18.7 participants.

The objective of the questionnaire was not to find out the total number of teachers served by in-service events, however some insight can be gained from the responses of these institutions. By using the most conservative estimate of the total number of in-service events offered (n=149, see Table 1), times the average number of participants (n=18.7), one can estimate that approximately 2790 teachers were served by this group of institutions.

Financial Responsibility

The data suggested that 66% of colleges and universities are financially responsible for at least some of the in-service events they offer. State departments of education played a role in funding in-service at 41% of the institutions. One institution, which reported delivering more than 10 in-service activities, stated that grant or project monies paid for most activities. Given ever shrinking college budgets and the reported high level of institutional funding of in-service activity, one begins to wonder if budget reductions are also reducing the number of in-services offered. Or, perhaps the financial sponsorship reported by institutions more accurately reflects graduate courses in technology education. Declining funding of higher education in many states could be a significant problem in the future. A listing of the agencies responsible for funding in-service events is presented in Table 6.

Table 6
Agency Financially Responsible for In-service Activities. (Respondents checked all categories that applied. Maximum n=29 in any category.)

Agency Financially Responsible	Number of Institutions	Percent of Institutions
College or University	19	66%
State department	12	41%
Grant funding	7	24%
Local school district	2	7%
Technology Education Association	1	3%

Outcomes of In-service Activities

Respondents were asked to evaluate the outcomes of the in-service activities based on actual classroom observation or follow-up studies of participants. For example, did the in-service result in a change of classroom practice? Twenty-four of the respondents completed this section. Fourteen institutions (48%) reported that the materials or instructional practices presented at the workshop had been implemented by participating teachers. Nine (31%) institutions noted that changes in practice had been observed and one institution reported that the outcome of their in-service was unknown.

On a yes-no question, 11 institutions reported that data had been gathered on the effectiveness of any in-service activities offered during the past year and 18 (65%) reported no follow-up activity. Types of follow-up included after session evaluation forms and follow-up questionnaires to teachers. Of those institutions that reported no follow-up workshop evaluation, one respondent noted that the office of continuing education fulfilled this function.

Although respondents indicated that changes had occurred as a result of in-service programs, it is unclear how respondents arrived at this conclusion or how many teachers actually implemented the content. Further, the majority of institutions did not collect data on the effectiveness of their in-service offerings. Therefore, reports that instructional changes had occurred as a result of attending workshops are not necessarily supported by documentation.

Participant Support

The last area explored in this study was the way in which classroom teachers were supported or reimbursed for attending in-service activities. Typical types of support included release time, travel reimbursement, and paid substitute teachers. Other forms of teacher support noted by respondents included "recertification points," and software manuals, such as AUTOCAD, provided by vendors. Almost half of the institutions reported "no support" for participating teachers. Table 7 presents a tabulation of the ways in which teachers were supported and the source of that support.

Table 7
Types of Financial Support Provided to Teachers For Attending In-service Activities (Respondents checked all categories that applied. Maximum n=29 in any category.)

Type of Support	School District	State	Grant	Other	Totals
Release time	9	2	1	1	13
Travel expenses	8	4	2	0	14
Paid substitutes	9	2	1	0	12
No support					14

Conclusions

Colleges and universities that are active in pre-service technology teacher preparation are actively involved in in-service and professional development for classroom teachers. The in-service activities provided by this group of institutions typically emphasized new technologies and teaching methods consistent with contemporary directions in technology education.

While university personnel assumed the leadership role in a large majority of in-service events, topics were usually selected and planned with some form of classroom teacher input. Teacher input is obviously critical to the development of effective in-service. As Guskey (1986) noted, teachers who participate in in-service look for knowledge and skills that can potentially expand their teaching capabilities. Thus, the solicitation of teacher input keeps in-service content on-track with teacher needs.

Summer workshops and teacher institute days were the most common formats for the delivery of in-service professional development. Although these types of sessions are commonly used to initiate program improvements, researchers such as Browne and Keeley (1988) and Lambert (1988) suggested that continued on-site follow-up is required if teachers are to adopt changes in classroom practice. It appears there is a need for colleges and universities to develop long term relationships with in-service participants.

Related to the idea of long-term relationships with participants, it was found that little follow-up and evaluation of the effectiveness of in-service activities is occurring. Follow-up is important for at least two reasons: (a) to ascertain whether the desired educational outcomes are being achieved, and (b) to indicate if money spent on in-service actually made a difference in teaching practices. Two-thirds of the institutions reported assuming some of the financial responsibility for in-service activities. Effective follow-up may assure that this money is spent wisely.

Another possible cause for concern is that approximately one-half of the institutions offered in-service sessions with no monetary or release time support of teachers who attend in-service professional development activities. This is not consistent with recommendations by authors such as Lodge (1989) who indicated that it is important that teachers receive the monetary, time, professional and social support needed to accomplish the in-service goals.

Recommendations for Practice

Based on the conclusions of this study the following recommendations were derived:

1. In order for the technology education profession to receive the best value for scarce in-service resources, colleges and universities that offer activities must begin to implement a more effective means of evaluation and follow-up.
2. Providers of in-service programs may consider varying the location and timing of programs and offering workshops at nominal (or no) cost to attract greater numbers of teachers or a different segment of teachers other than those served by current arrangements.
3. Given continual pressure on institutional budgets, colleges and universities need to find ways of funding in-service on a consistent basis, independent of institutional funding.

Two additional items deserve some consideration. In conducting this study the researchers found limited information on in-service practices in technology education. Therefore, it would be helpful if results from successful in-service programs were disseminated in widely read publications such as *The Technology Teacher*. This could serve to promote and share effective in-service methods.

Further, several of the written comments by respondents suggested an emphasis on in-service activities that promote teachers-teaching-teachers. It seems logical then, that college and university personnel need to collaborate with other stakeholders in technology education to develop strategies to increase the involvement of technology education teachers in the planning, presentation, and evaluation of in-service activities.

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Simulating Design in the World of Industry and Commerce: Observations from a Series of Case Studies in the United Kingdom

Howard G. Denton[1]

Introduction

A requirement of the United Kingdom's National Curriculum is that all children gain economic and industrial understanding through aspects of the subject Design and technology (DES, 1990). To some extent, visits to industry, visiting speakers, work placements and simulations answer this requirement, but each has limitations. While a good teacher will use a variety of teaching techniques, the costs of visits and placements are high, so simulation offers an apparent cost effective technique.

The author's experience visiting many schools in the UK indicates that few teachers appear to use simulation or realize the potential of the technique. This observation formed the start point for this inquiry which focused on a type of simulation in which small teams of children simulate companies designing and making products for the market place. An illuminative paradigm (Parlett & Hamilton, 1983) was considered appropriate initially, using unfocused observation, informal interviews with pupils and teachers and, in some cases, Nominal Group Technique (Lomax & McLeman, 1984; O'Neil & Jackson, 1983). These techniques allow categories of factors to emerge as the study proceeds rather than having observers report on the frequency of factors which the researchers have decided to focus upon. On the negative side, such techniques do not allow accurate quantification of data and reliability can only be established when a category or factor emerges repeatedly over many different cases and via different observers. However, signposts for further, more focused research can be established.

There were two broad goals of this study: 1) a fuller understanding of these simulations, (allowing more focused subsequent enquiry); and 2) the subsequent dissemination of this understanding to teachers. The inquiry has illuminated some of the advantages and limitations of this approach to simulation. It has also shown that there is a place for unfocused observation as

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a technique in beginning to understand learning in “live” situations, where variables cannot be fully defined or controlled. A number of findings have arisen which would not have been uncovered if observers had operated focused schedules of observation.

A Review of the Literature

Simulation

Rediffusion (1986 section 1.3) stated that “Simulation, as used in training, is a dynamic representation of a system, process or task.” The term “dynamic” is important. Participants interact with the simulation and each other. Roebuck (1978, p. 107) reinforced this point describing simulations as: “...organizational devices for arranging interactions.” At the core of simulations, therefore, are a model (the “representation” in the Rediffusion definition) and the interaction of participants with that model and with each other.

The range and application of models used in designing has been described by Evans (1992) and Tovey (1986). Designers use models to accelerate and develop their thinking on a task; for example, a model of the systems in a dump truck. When a similar model is used to teach people how these systems interact by allowing them to work directly with it, it becomes a simulation. The simulation model does not have to be physical. It could be computer based, verbal, or written description.

Turning to interaction, Jones (1989) stated that participants should operate with autonomy within the simulation. Participants should be allowed to make their own mistakes; the iterative nature of the simulation should then be used to identify these and allow the participant to rehearse new strategies. The teacher's role, therefore, is threefold: establishing the “environment” of the simulation; monitoring the simulation in action; and assisting with de-briefing to maximize learning (Dawson, 1990; Glandon, 1978; Perry & Euler 1988; Rediffusion, 1986; Shirts, 1976; Thatcher, 1986).

Simulations are often confused with academic games which are: “...contests usually amongst player opponents operating under rules to gain an objective” (Adams, 1977, p. 39). The important difference is the rigidity of the rules. Jones (1990, p. 355) considered games to be “...closed systems in which the rules are self contained and self justifying.” In a simulation there may be rules or a general description of the principles by which the model operates. These are not rigid rules but may operate dynamically. A game is a closed system with specific objectives; a simulation is open. The objective of a simulation is one of assisting participants to learn from the experience and to be able to transfer that learning to a real world context.

Simulations in relation to teaching and learning

Some workers have pointed out that simulations are less effective for teaching factual knowledge than other techniques of teaching and learning (Jones, 1990; Percival, 1978). The main advantages are in exercising and reinforcing previously learned knowledge. For example a pilot uses a flight simulator to practice “textbook learning” of how to react to emergencies. In simulations exercising personal interactions, Shirts (1975) pointed out that the simulation designer should work from a “general intent” rather than attempt learning of a specific knowledge base. Having said this, it is possible to embed more conventional learning within the context of a simulation. For example, a teacher may interrupt a simulation to teach concepts or skills which emerge as being necessary at a particular point.

The key to what must necessarily be a brief survey of simulation in relation to teaching and learning is the concept of transferability of learning from the simulation to other contexts. Putnam (1987) and Voss (1987) have shown that transfer will be weak or non-existent unless teachers use various techniques to assist pupils in this respect (Adey, 1990; Klauer, 1989). These are discussed below.

An essential, though not unique, feature of simulation is a cycle of briefing, activity, and debriefing. Simulations can be flexible, enabling the teacher to start with a short cycle based on a very simple model and through a series of iterations assist pupils build confidence (Adams, 1977). This ties with cyclical models of learning such as Hampden-Turner's (1986). Perry and Euler (1988) pointed out that the iterative nature of simulations help pupils recognize the relevance of their work and Megarry (1976) showed how learning improves once learners recognize the importance of the work. Thatcher (1986) pointed out that at de-briefings, the teacher should encourage learners to be active in analyzing their reaction to the simulation. A teacher-imposed de-brief was of far less value.

Simulation texts often use the term “fidelity” in discussing the degree to which a simulation represents real life (Rediffusion, 1986). Evans and Sculli (1984) showed that the learning benefits from a simulation are not related to high levels of fidelity. Boreham (1985) showed that learning transfer may be improved by lower fidelity as this removed peripheral factors and helped the learner to concentrate on central factors. After several iterations, however, increased fidelity may improve the learner's confidence in that context.

Percival (1978) reported that simulation appeared to improve motivation in children and particularly for those of lower intellectual ability. Lower levels of fidelity in simulation models may be a key to this. Evans and Sculli (1984) showed that competition can have a motivational effect within simulations. This, however, diminished if the levels of competition were allowed to develop. What levels of competition are most effective in raising motivation appear to be highly problematical to predict. It could be expected that the reaction to a competitive situation will be individual and the overall effects in a class complex.

One feature often used in simulations is that of extended periods of time totally focused on the simulation rather than pupils following a conventional timetable. Lindsay (1988) pointed out the time wasted in a conventional timetable due to stopping, starting, and the need to constantly re-focus pupils' direction. Grimes and Niss (1989) and Parlett and King (1970) showed that "concentrated time," rather than conventional time tabling, developed higher levels of motivation and that levels of learning were at least as good as learning the same material within a conventional timetable.

Research Design

This inquiry used a series of ten case studies of simulations. The general aim was an increased understanding of this type of work. More specifically, it was intended to discover more about childrens' reactions to this form of work; to identify the limitations of the approach and to build an understanding of how such simulations should be planned and executed for maximum effectiveness.

All case studies were "live" in that the teachers involved had their own teaching and learning objectives; the inquiry had to fit around these. It was necessary to be eclectic in data collection methods whilst ensuring that the general principles of data triangulation (Cohen and Manion, 1980) were followed. The methods used are described below and in Table 1.

Observation

Direct participant and non-participant observation were used in all cases. The reflexive limitations of observation were reduced by triangulation (Cohen & Manion 1980) in time, investigator, and location. Time, in that the case studies covered a period of three years. Investigator, in that there were observations from the author, teachers and other researchers. Location, in that contexts and events were studied in different geographical and social areas, both within schools and on a residential course.

Observation was open-ended. Observers were briefed to note anything of interest but particularly to evaluate the effectiveness of the simulations in relation to their planning and execution, the response of the children, and any difficulties which arose. Normally, observers compared notes at meetings immediately after each session. These meetings allowed free discussion, helping observers to recollect any points they may have witnessed but been unable to note. Multiple observers helped to limit the problems of idiosyncratic observation.

The advantage of such open-ended observation is that it may identify factors which the researcher has not identified prior to the exercise. The disadvantage is that it prevents a reliable measure of numbers of incidence.

Such an approach has value in the initial study of such situations. The results can be used to identify more focused questions for further research.

Interview

During any case study there were episodes where observers moved in and held informal, open-ended interviews with individuals or teams. These interviews were used to clarify points raised by observation and as such did not use an interview schedule. Data took the same form as the observations; written notes which reported the meaning of the interview rather than verbatim transcripts.

A variation on the interview was the group report back session used in case study 3. Here a group of 25 teachers from 6 schools reported back on innovation in their own schools based upon the training course conducted by the author. The author was able to question these teachers in order to clarify any points from their presentations.

Nominal Group Technique (NGT)

NGT is a form of group brain-storming technique used to evaluate learning programs (Lomax & McLeman, 1984; O'Neil & Jackson, 1983). It was used to gather data in case studies one, two, and five with sample sizes of nine, nineteen, and eighty respectively. NGT differs from group discussion techniques in that interaction is restricted to prevent associated problems, such as minority /majority opinion (Levine & Russo, 1987). Nevertheless, the technique seeks to capitalize on the potential of group discussion.

Group(s) were established with a maximum membership of 18. Scribes were appointed and each group asked to evaluate the simulation they had just had. Anonymity was assured. Members were allowed ten minutes to note their own responses. Discussion was not allowed so that dominant personalities were prevented from imposing directions. Each member then read out their first five responses in turn. Once all had listed five, the process was repeated, with members listing their next five and so on. Members could use the points raised by others to develop their own thinking and adding to their list. When there were no new points to add, members could ask for clarification of any points. No criticism was allowed. The scribe then consolidated the list with the agreement of members. This was done to reduce the list to a series of statements with which one could agree or disagree. Members then responded with a number weighting from 1(disagree or of low importance), to 5 (strongly agree or of high importance).

The data gained were entered in a spreadsheet where the mean weighting and standard deviation were calculated for each statement. The results appear to be quantitative but the reader should remember they are qualitative observations from multiple participants and observers. The number and standard deviation allow judgment on the strength of feeling for a statement. The detailed results and initial analysis are beyond the scope of this paper and can be found in Denton (1992).

Reduction and Analysis of Data

All data generated was in the form of written notes or statements. These were reduced to the minimum number of words without losing the meaning. Lists were then produced which could be scrutinized for emerging categories; a very basic form of factor analysis. These categories, for example observations or NGT responses which referred to perceived increased levels of student motivation, could be given a degree of reliability (non-numerical) by the frequency with which they were made and the degree to which they triangulated by being made by different observers and different methods. NGT results were more straightforward, producing numerical weightings of participants' agreement /disagreement with each statement.

This process was done separately for each case study. It was then possible to compare data across the ten case studies. If specific observations from different case studies aligned then a degree of reliability was established, differences lowered any reliability. From this process emerged categories of observation which had some reliability in the contexts of the case studies. As the results generated are necessarily verbal descriptions and lengthy it is inappropriate to follow convention and list all results before discussion. The basic categories established are, therefore, reported and discussed point by point.

Treatment in the case studies

There were ten independent studies. These are summarized diagrammatically below. The simulations varied from hours to five days. In some cases, the simulations were run in normal lessons over a period of weeks. In others, the timetable was suspended and the event run over periods of up to five days of concentrated time. Despite the differences all followed a general model. Pupils were placed into teams of 3 to 7. These were selected on the basis of mixed ability, gender and ethnicity. This was done to achieve broad based teams without natural peer groups. A task was set: a response to a design opportunity such as the production of prototype meals and packaging for inter-city buses.

Each team was a “company,” developing the product and launching it on the market at a trade exhibition. The product had to be designed and developed, including cost. A simplified business plan had to be established, point of sale advertising developed and a sales display set up. A deadline was given, usually the last morning. Demonstrations (“inputs”) were given at specific times, but could be attended by only one member from each team. This member was responsible for gathering information which had to be communicated to the team. At the start of each working session a briefing was held. This reminded teams of the key events of the session and raised observations on performance in any previous session within the simulation. A debriefing was held at the end of each day, or working session, in which pupils evaluated the experience up to that time.

Table 1
A Summary of Case Studies

Case Study	Average Age	Number in Sample	Timetable or Dedicated	Residential or in School	Time	Evaluation method
1	17 yrs	9	timetable	school	2 hrs	teacher & researcher observations, NGT
2	12 yrs	19	timetable	school	10 wks at 90 mins per	teacher & researcher observations, NGT
3a	12 yrs	25	dedicated	school	1 day	teacher observations
3b	15 yrs	50	timetable	school	8 wks at 35 mins	teacher observations
3c	14 yrs	100	timetable	school	4 wks in timetable + 1 day	teacher observations
3d	13 yrs	100	pilot in TT + 1 day dedicated	school	4 wks in timetable + 1 day	teacher observations
3e	17 yrs	50+	dedicated	school	2 days	teacher observations
3f	12 yrs	100	dedicated	school	2 days	teacher observations
4	15 yrs	60	primed in timetable + 5 days dedicated	school	5 days	teacher observations researcher interview
5	17 yrs	80	dedicated	residential	5 days	teacher & researcher observations, observations from visiting researchers, team-work profiles, NGT

On the final session, “trade displays” were set up and a simulated “market place” held. For this teams took the role of buyers, having a purchasing power of £1000. This had to be spent using criteria that the buyers felt were important. The financial position for each company was established on the basis of orders placed. In parallel staff prepared written feedback on the design work. Their assessment focused on the team product rather than trying to identify the work of the individual. A final debrief was held. These opened a great many points for discussion.

Results: Categories and Discussion

The nature of the data and the categories established are necessarily qualitative. To follow convention and report the results fully followed by discussion would mean much repetition. The categories are, therefore, defined and described below with an immediate discussion.

Pupil Motivation

All teachers in the studies reported that they observed an increase in pupil “motivation” over that they would expect for “normal” design and technology work in their school. Discussion with teachers enabled an agreed working definition of “motivation” as the level of purpose and energy demonstrated by pupils in relation to their work. These observations were by teachers who normally worked with the pupils, therefore the level reported was a simple comparison and not an objective measure. However, when each of thirty teachers involved with the case studies reported a perceived increase in level of pupil motivation, some degree of reliability is gained even if it is not possible to put a numerical measure to it. This was particularly noticeable in the case of pupils teachers felt were normally less motivated and less intellectually able. This confirms the findings of Percival (1978) who, in a literature survey, claimed evidence that simulation may boost motivation and that simulation may have a marginally more positive effect on the motivation of “less able” pupils. Adams (1977), writing on simulation games, also considered that participant motivation is increased.

The increase in motivation may be largely due to novelty effects. To the researcher, such effects are not helpful. However, it is worth taking the perspective of the teacher. Could such novelty effects be used in order to boost motivation at appropriate points in a learning program? Questions would need answering as to the frequency with which such events were run before they became “normal” and novelty effects diminished.

Pupils' Perceptions of Relevance

A number of NGT results related to pupils' perceptions of the relevance of the simulations to their futures in relation to “normal” design and technology work. Statements such as “similar to real life work,” “good working under pressure,” and “good for developing personalities and communications” all have high mean scores and low standard deviations meaning there was strong agreement amongst all pupils.

An increase in pupils' perceptions of relevance may assist attention and motivation. Megarry (1976) observed that it is only when the learner recognizes the importance of the question that answers are remembered or understood. A less obvious factor was the way in which the iterative structure of the simulations supported teachers in helping pupils to recognize this relevance. This supports Perry and Euler's (1988) observations. The mechanism for this was the regular de-briefing and re-briefing sessions. Pupils were helped to reflect on their experience and teachers were able to "build the simulation" by reminding pupils of the context and acting much as a sports coach does during match breaks. In the work of Adey et al. (1990) reflection emerged as an important strategy for promoting the transfer of learning.

The iterative nature of simulations assist the learner in recognizing relevance. The knowledge gained is fed into the next loop of the simulation. This iterative model of learning has been highlighted by several writers on simulation including Thatcher (1986) and Laveault and Corbil (1990). They propose cyclic models of concrete experience — reflective observation — abstract conceptuality — active experimentation. As each cycle is completed, the person rises to a new level and the cycle continues (see also Hampden-Turner, 1971). Similarly, the motivational effect is supported by Myers (1990) who claims that Academic Engaged Time (AET) can be improved by positive feedback.

Motivation in Relation to the Participation of Industrial Staff

All case studies incorporated a simulated commercial environment. Some also incorporated commercial and industrial staff into the simulation. There were indications that pupil motivation increased when these staff were involved. This observation is based on direct observation of pupil behavior and informal interviews. As none of the case studies allow a direct comparison of involvement of commercial/industrial staff with non-involvement this observation must necessarily be seen as subjective and lacking reliability. Nevertheless the indications were strong enough to merit reporting as a signal that other researchers may find interesting to follow up.

This appears to again support the work of Perry and Euler (1988) and Megarry (1976) discussed above. The case studies had been structured to follow the advice of Shirts (1975) and concentrated on exercising and reinforcing knowledge rather than attempt specific factual learning. However, there are dangers in loading simulations with detail (Boreham, 1985) and particularly in using them to promote factual learning (Adams, 1977, Jones, 1990; Percival, 1978). Excessive detail (high fidelity) detracts from the central aims of the simulation by making the pupil focus on detail such as remembering facts rather than exercising learning in a context. It is also worth contrasting the work of Earl (1990) who found that the “response” to a simulation was dependent on the context being identifiable by the pupils. He gives an example of pupils in Scotland responding to a desert survival simulation. When this was rewritten as a sea survival exercise the response was improved. The tasks and commercial context within the case study simulations appeared to be well within the pupils' cultural identity.

Low levels of fidelity may also stimulate debate at debriefings as pupils attempt to seek clarification of the context and to point out the simplicity of the model. This debate could lead to better understanding. Pupils need to be able to recognize when they need more information and develop techniques to find it.

Suspended Timetable

Some case study schools operated the simulations within a normal timetable over a period of weeks. Other schools suspended the timetable and operated the simulation over the whole school day for up to five days of “concentrated time.” There were no schools which ran both concentrated time and “in timetable” simulations, so a direct comparison of motivational levels is dependent on the observations of the author. There were many indications that motivational levels developed to a higher level in the concentrated time studies. Typically staff had difficulties getting children to stop working and leave rooms at break, lunch times or after school. Teachers also reported that in concentrated time studies there were many requests from pupils for more work of that kind.

These effects may be due to a novelty factor, but there was also the possibility that operating in concentrated time assists pupils develop an identification with the simulation. Breaks or demonstrations inhibit this process through two mechanisms. First, breaks prevent pupils from building an intense identification with the simulation — “living the simulation.” Secondly breaks disturb what levels of identification are built, meaning that staff have to attempt to re-build identification on rejoining the simulation. It would be reasonable to assume that the longer the break the more difficult it would be to re-build the identification. An over-night break during a five day suspended timetable event is easily “repaired.” A week long break after only an hour of work, if a simulation is run in timetable, means that levels of identification were not built to the same extent and are more difficult to rebuild.

The manner in which breaks or demonstrations are managed and presented may be an important factor in determining whether an effective link is re-established with the simulation. No specific data has been gathered on this aspect. However, it is hypothesized that the way in which inputs are closed would be important, as would be the manner in which staff re-direct learners to the simulation. These questions would need to be resolved by closely focused observation of inputs of differing length and structure in a series of simulations.

Roles/Freedom to Interpret/Time-Planning

Jones (1990) made the important point that participants in a simulation must be allowed to interpret their roles with autonomy. In the case studies, this principle was taken further and pupils were left to develop their own team structure rather than have it imposed by staff; specific roles were not set. Teams were deliberately made up of pupils who were not in friendship groups in order to make them work at establishing relationships rather than rely on those already established on social, cultural or gender grounds.

In nearly all cases, teams claimed they had developed cooperative structures rather than conventional management pyramids. This was an interesting observation of the cultural morés of the sample of English pupils. Observation showed that most teams struggled in the early stages of these simulations because they had to establish a working structure and identify how they were to tackle the task. The five day suspended timetable events, particularly, exhibited a regular pattern of difficulties and struggle over the first two days followed by a rapid rise in confidence, motivation and application.

It is interesting to contrast this with the work of the Cognitive Acceleration through Science Education (CASE) Project (Adey et al. 1991). Here the principle of “cognitive conflict” was put forward as a key element in developing the ability to think. The CASE Project considers that pupils need to be made to confront and struggle with problems if they are to develop reasoning. They criticize much school work as being non-challenging:“...there is a strong temptation for teachers and learners to enter into an unspoken conspiracy to avoid undue mental effort.” (Adey et al. 1990 p. 2)

In the case studies, by not pre-ordaining specific roles and giving freedom to manage the task, teams were caused to confront questions of suitable control and management structures. The very act of struggling to establish effective control with approaching deadlines may develop self confidence and motivation together with the “thinking skills” reported by CASE. De-briefing sessions represent the “reflection” which CASE also considered important. The CASE results indicated both long term effects and a general one which was demonstrated by better achievement in widely different subject areas.

Deadlines

All the simulations set clear task deadlines which modeled a product launch at a trade exhibition. There was evidence from the NGT results that pupils saw working to deadlines as very relevant. As deadlines approached work rates increased considerably. Pupils were observed to put in far more time than they were required, typically working through meal breaks or after school.

It was noticeable that this had the effect of making teams think more about the economy of time use in relation to design. Teams had to establish their own internal deadlines and effectively establish a critical path analysis. The pupils involved were generally used to having more time in Design and technology lessons to explore and develop their ideas without this pressure.

It is interesting to contrast the "economic" style of design within the simulations with reports on Design and Technology work in United Kingdom schools by Her Majesty's Inspectors (HMI, 1992) and Smithers & Robinson (1992) for The Engineering Council. These criticized Design and Technology in the UK for allocating insufficient time to making activities and over-emphasizing "paper" design. The approach to designing within the case studies appears to have helped pupils focus on the ultimate aim of design in a commercial context — the efficient and effective production of products.

Pupil-Staff Relations

Staff and pupils reported a change in their relations. The effect was positive, represented by improved pupil respect for staff. There were indications that staff, in turn, viewed pupils differently but the results were not specific enough on this point.

Teachers' Reactions — Need for Contact

Much of the literature on simulation emphasizes the importance of allowing pupil autonomy (Jones, 1989; Shirts, 1975). This principle was built into the simulations and certainly NGT results pointed out how pupils valued "being left alone more." Good teachers need not reduce pupil autonomy when working closely with pupils if they manage the interaction well. However, close contact certainly tends to reduce autonomy. Many teachers managing the case studies reported that they found it difficult to break contact and allow pupils autonomy and involved themselves as much as they normally would. On interviewing, these teachers they admitted that they "needed" close contact with the pupils and their work and found the distance necessary to give pupils autonomy uncomfortable.

This is interesting; these particular teachers appeared to need close contact in order to gain feedback on the progress of learning, even though they could recognize the logic of allowing pupils autonomy within the simulation. All these teachers were inexperienced with simulation techniques and it may be possible to hypothesize that, with experience, they would be able to give more autonomy. The ability to break contact with pupils offered teachers far better opportunities to observe pupils and then to intervene selectively, when appropriate.

Competition

Pupils did not react to the competitive aspect of the commercial context as expected. Despite the inter-team competition explicit in the model, there were many examples of inter-team cooperation by individuals. In pupil NGT responses, there was little evidence of them seeing competition as being either very relevant or motivational.

Competition in commerce is inescapable. Evans and Sculli (1984) considered that competition does increase motivation and sustain effort in simulations and games. They observed, however, that a highly competitive environment detracts from the learning potential. This may be accepted but there is a clear cultural and age gap between the managers in the work quoted above and the pupils in the case studies. It is also possible to draw a parallel with the point above that teams preferred to establish cooperative models of management rather than typical pyramid models. There appears to be a sub-cultural ideal which sees cooperation as positive but competition as being negative, though this would require more work before it could be reliably stated.

It is interesting to compare this with research in the area of management studies where workers such as Buchanan (1989) report on the potential value of management models which "flatten" the management pyramid and give increased responsibility and autonomy to people. Experiments in various companies have reduced the number of management levels and increased the autonomy and responsibility of all including "shop floor" workers. This research has shown output and worker relations have improved while time off on sickness leave has dropped in these companies.

Conclusions

The case studies indicated that modeling design contexts, of the particular type indicated, could generate a reliable increase in motivation. This reinforces the findings in the literature. The studies raised a number of potential pitfalls in managing simulations which teachers would have to be aware of if they were not to lead to negative feedback for pupils. The simulations did not attempt to introduce factual learning and the literature indicates that this would not have been appropriate. It appears better to use simulations to periodically exercise and consolidate learning in a context which will increase pupils' perceptions of relevance. If simulations are used in concentrated time, by suspending the timetable at appropriate points, perhaps only once a year, the novelty effects of such an approach will be maintained. In this way novelty-induced increases in motivation may be used to help pupils to recognize what they can achieve with appropriate effort, so building their self knowledge and self confidence. Such simulations can also be used to help pupils understand the potential dangers of prolonged high level work rates and other questions on the moral elements of designing in society. These can be drawn into discussion during the end of simulation de-brief. The value of iteration and reflection were confirmed by the case studies and could be valuably applied more thoroughly to "normal" design and technology project work.

The observation that many teachers had difficulties in standing back and allowing pupils autonomy was unexpected. This underlines the importance of in-service support for teachers as they adopt teaching/learning techniques with which they are not familiar. If teachers were to adopt such techniques without suitable preparation there are indications that learning could be ineffective and may lead to damaging experiences for pupils.

Similarly the observation of pupils' preference for cooperative management models and resistance to competition were unexpected and interesting. This requires more work but would indicate that English pupils, whilst able to recognizing the value of cooperative work practices, also need help to be able to use competition in a positive manner.

The inquiry methodology adopted has been useful in identifying factors within the simulations observed of interest and relevance to teaching and learning. The obvious limitations of the approach means that there can be no claim to external validity in a technical sense but there is some value for practitioners and pointers for researchers. The next step is to try to identify the effects of specific factors, such as the use of concentrated time periods in relation to conventional time tabling or the introduction of personnel from industry and commerce into design and technology project work. Appropriate methodology will have to recognize the difficulties in separating out the variables in live learning situations.

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Effects of Multiple-Choice and Short-Answer Tests on Delayed Retention Learning

W. J. Haynie, III[1]

Abstract

This research investigated the value of short-answer in-class tests as learning aids. Undergraduate students (*n*=187) in 9 technology education classes were given information booklets concerning "high-tech" materials without additional instruction. The control group was not tested initially. Students in the experimental groups were either given a multiple-choice or a short-answer in-class test when they returned the booklets. All groups were tested for delayed retention three weeks later. The delayed retention test included subtests of previously tested and new information. Both short answer and multiple-choice tests were more effective than no test in promoting delayed retention learning. No difference was found between short-answer and multiple-choice tests as learning aids on the subtest of information which had not been tested on the initial tests, however, multiple-choice tests were more effective in promotion of retention learning of the information actually contained in the immediate posttests.

This study compared two types of teacher-made in-class tests (multiple-choice and short-answer) with a no test (control) condition to determine their relative effectiveness as aids to retention learning (that learning which is still retained weeks after the initial instruction and testing have occurred). The investigation involved instruction via self-paced texts, initial testing of learning, and delayed testing 3 weeks later. The delayed tests, which included both previously tested information and novel information that had not been previously tested, provided the experimental data for the study.

Background

The importance of testing in education makes it an important topic of continuing research. As technology education evolves to emphasize more cognitive learning, the time devoted to testing and the effects of testing will become increasingly important. Most of the research on testing which has been reported

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in recent years has concerned standardized tests (Bridgeford, Conklin, and Stiggins, 1986). Most of the evaluation done in schools, however, is done with teacher-made tests (Haynie, 1983, 1991, 1992; Herman & Dorr-Bremme, 1982; Mehrens, 1987; Mehrens & Lehmann, 1987; Newman & Stallings, 1982). The available findings on the quality of teacher-made tests cast some doubt on the ability of teachers to perform evaluation effectively (Burdin, 1982; Carter, 1984, Fleming & Chambers, 1983; Gullickson & Ellwein, 1985; Haynie, 1992; Stiggins & Bridgeford, 1985; Wiggins, 1993). Despite these problems, Mehrens and Lehmann (1987) point out the importance of teacher-made tests in the classroom to evaluate attainment of specific instructional objectives. Evaluation by teacher-made tests in schools is an important part of the educational system and a crucial area for research (Haynie, 1990a, 1990b, 1991, 1992; Mehrens & Lehmann, 1987; Wiggins, 1993).

One method of testing that has received little attention in the literature, however, which is popular in many educational settings, is the use of short-answer test items. Short-answer items are relatively easy to prepare (Haynie, 1983) and may be scored more quickly than essay items. They are not as objective as multiple-choice items because they sometimes do not give adequate information to evoke the desired response even from students who know the subject well. Despite this limitation, they may be useful on teacher-made tests because there is good evidence to suggest that many teachers are not capable of authoring truly clear and effective multiple-choice items (Haynie, 1983, 1992). Since many teachers do use short-answer items, their usefulness in promotion of retention learning is worthy of research.

Multiple-choice tests, take-home tests, and post-test reviews have all been shown to promote retention learning in previous studies (Haynie, 1990a, 1990b, 1991, in press; Nungester & Duchastel, 1982). However, announcements of an upcoming test did not have a positive effect on retention learning without a test actually being given. It appears that increased studying due to anticipation of a test did not result in better retention — only the act of taking the test increased retention (Haynie, 1990a). No studies were found that investigated the effects of short-answer tests on retention learning which is the thrust of this research. Research on the effects of tests on retention learning within the context of technology education classes and the value of the learning time they consume is limited to the studies cited above.

Purpose and Definition of Terms

The purpose of this study was to investigate the value of in-class multiple-choice and short-answer tests as aids to retention learning. "Retention learning" as used here refers to learning which lasts beyond the initial testing and it is assessed with tests adminstered 2 or more weeks after the information has been taught and tested. A delay period of 3 weeks was used in this study.

"Initial testing" refers to the commonly employed evaluation by testing which occurs at the time of instruction or immediately thereafter. "Delayed retention tests" are research instruments which are administered 2 or more weeks after instruction and initial testing to measure retained knowledge. (Dwyer, 1968; Dwyer, 1973; Duchastel, 1981; Nungester & Duchastel, 1982; Haynie, 1990a, 1990b, 1991, in press). The delayed retention test results were the only data analyzed in this investigation.

In addition to studying the relative gains in retention learning acquired by students while they take a test, an effort was made here to determine whether information which has been studied but which does not actually appear on the immediate posttest will be retained in addition to that material which is on the test. This study also examined whether multiple-choice and short-answer tests differ in their effectiveness for promoting retention of both tested and untested material. The research questions posed and addressed by this study were:

1. If delayed retention learning is the objective of instruction, does initial testing of the information aid retention learning?
2. Does initial testing by short-answer tests aid retention learning as effectively as initial testing with multiple-choice tests?
3. Will information which is not represented on initial testing be learned equally well by students tested via short-answer and multiple-choice tests?

Methodology

Population and Sample

Undergraduate students in 9 intact technology education classes were provided a booklet on new "high-tech" materials developed for space exploration. There were 187 students divided into three groups: (a) Multiple-choice test (Group A, n=63), (b) Short-answer test (Group B, n=64), and (c) No test (Control, Group C, n=60). All groups were from the Technology Education metals technology (TED 122) classes at North Carolina State University. Students were majors in Technology Education, Design, or in various engineering curricula. Students majoring in Aerospace Engineering were deleted from the final sample because much of the material was novel to other students but had previously been studied by this group. All groups were team taught by the researcher and his graduate assistant. Treatments were randomly assigned to each section. Random assignment, deletion of students majoring in Aerospace Engineering, and absences on testing dates resulted in final group sizes which were slightly unequal.

Design

At the beginning of the course it was announced that students would be asked to participate in an experimental study and that they would be learning subject matter reflected in the newly revised course outline while doing so. It was also pointed out, however, that formal tests had not been prepared on the added material, so this portion of the course would not be considered when determining course grades except to insure that they made a "good, honest attempt." All other instructional units in the course were learned by students working in self-paced groups and taking subtests on the units as they studied them. The subtests were administered on three examination dates. The experimental study did not begin until after the first of the three examination dates to insure that students could see (and believe) that none of the eight regular subtests reflected the newly added subject matter.

During the class period following the first examination date, the subtests which had been taken were reviewed and instructions for participation in the experimental study were given. All students were given copies of a 34 page study packet prepared by the researcher. The packet was titled "High Technology Materials" and it discussed composite materials, heat shielding materials, and non-traditional metals developed for the space exploration program and illustrated their uses in consumer products. The packet was in booklet form. It included the following resources typically found in textbooks: (a) A table of contents, (b) text (written by the researcher), (c) halftone photographs, (d) quotations from other sources, (e) diagrams and graphs, (f) numbered pages, (g) excerpts from other sources, and (h) an index with 119 entries correctly keyed to the page numbers inside. Approximately one-third of the information in the text booklet was actually reflected in the tests. The remainder of the material appeared to be equally relevant but served as a complex distracting field to prevent mere memorization of facts. Students were instructed to use the booklet as if it were a textbook and study as they normally would.

Six intact class sections over a two year period were randomly assigned to Group A or Group B (three each). Both groups were told to study the packet and that they would be asked to take a test on the material in class one week later. Students were told that participation was voluntary and the tests would not affect their grades. Both groups were requested to return the packets on the test date also. Students were told that the purpose of the study was to examine the types of answers given on the tests to see if there was a difference in the way questions were approached. They were also again told that the results would not affect their course grades and that participation was voluntary.

In order to obtain a control group, three randomly selected sections of students in the same course during the two semesters of the next year were given the same initial instructions. However, instead of announcing a test, the teacher told the students that the material was newly added to the course and no subtests had been prepared yet — so they were simply lucky and would be expected to study the material as if they would be tested; however, they would not actually be tested. It is acknowledged that these students who participated in the study in a different year than the other two groups could have been a confounding variable; however, they did come from three intact class sections with the same teachers as the other groups. It was felt that this was the only way to insure that students truly believed they would not be tested on the material. If they had been mingled with the other two groups, they would have readily seen that some sort of testing had to occur sometime or there would be no data for the experiment from their group. This would have also spoiled the effectiveness of the evasive statements to the other two (experimental) groups that "types of answers" on the tests were the data of interest.

Three weeks later, all groups were asked to take an unannounced delayed retention test on the same material. They were told at this time that the true objective of the experimental study was to see which type of test (or no test) promoted delayed retention learning best, and that their earlier tests, if any, were not a part of the study data in any way. Students were told again that participation was voluntary. They were again asked to do their best and reminded that it did not affect their grades.

The same room was used for all groups during instructional and testing periods and while directions were given. This helped to control extraneous variables due to environment. The same teacher provided all directions and neither teacher administered any instruction in addition to the texts. Students were asked not to discuss the study or the text materials in any way. All class sections met for 2 hours on a Monday-Wednesday-Friday schedule. Some students in each group were in 8:00 a.m. to 10:00 a.m. sections and the others were in 10:00 a.m. to 12:00 noon sections, so neither time of day nor day of the week should act as confounding variables. Equal numbers of Fall Semester and Spring Semester students were assigned to each group. Normal precautions were taken to assure a good learning and testing environment.

Instrumentation

The initial tests were parallel forms of a single 20 item test. The short-answer version was identical to the multiple-choice form except that there were no alternatives from which to choose responses and brief prose answers were required. Multiple-choice items had five response alternatives. The same information was reflected in both tests. It must be noted that, in general, short-answer tests tend to be used more often and appear to be more effective with lower level types of learning (Haynie, 1983), therefore, the information in this study was taught and tested primarily at the first three levels of the cognitive domain: (a) knowledge, (b) comprehension, and (c) application.

The delayed retention test was a 30 item multiple-choice test. Twenty of the items in the retention test were alternate forms of the same items used on the initial in-class test. These served as a subtest of previously tested information. The remaining ten items were similar in nature and difficulty to the others, but they had not appeared in any form on either of the initial tests. These were interspersed throughout the test and they served as a subtest of new information. The subtest on new information was used to determine if retention learning gains were made during the study period or during the process of actually taking the tests — assuming that all of the information had been originally studied with relatively equal diligence, this information should be learned equally by all groups. If the type of test employed effected retention learning gains, then one of the tested groups would be expected to outperform the other one on the subtest of previously tested information.

The delayed retention test was developed and used in a previous study (Haynie, 1990). It had been refined from an initial bank of 76 paired items and examined carefully for content validity. Cronbach's Coefficient Alpha procedure was used to establish a reliability of .74 for the delayed retention test. Item analysis detected no weak items in the delayed retention test. Thorndike and Hagen (1977) assert that tests with reliability approaching .70 are within the range of usefulness for research studies.

Data Collection

Students were given initial instructions concerning the learning booklets and directed when to return the booklets and take the tests. The in-class immediate posttests were administered on the same day that the booklets were collected. The unannounced delayed retention test was administered three weeks later. Data were collected on mark-sense forms from National Computer Systems, Inc.

Data Analysis

The data were analyzed with SAS (Statistical Analysis System) software from the SAS Institute, Inc. on a microcomputer. The answer forms were electronically scanned and data stored on floppy disk. The General Linear Models (GLM) procedure of SAS was chosen for omnibus testing rather than analysis of variance (ANOVA) because it is less affected by unequal group sizes. A simple one-way GLM analysis was chosen because the only data consisted of the Delayed Retention Test means of the three groups. The means of the two subtest sections were then similarly analyzed by the one-way GLM procedure to detect differences in retention of previously tested and novel information. Follow-up comparisons were conducted via Least Significant Difference *t*- test (LSD) as implemented in SAS. Alpha was set at the $p<.05$ level for all tests of significance.

Findings

The means, standard deviations, and final sizes of the three groups on the delayed retention test (including the two subtests and the total scores) are presented in Table 1. The overall difficulty of the test battery and each subtest can be estimated by examining the grand means and the range of scores.

The grand mean of all participants was 16.63 with a range of 3 to 28 on the total 30 item test. The grand mean on the 20 item subtest of previously tested material was 12.32 with a range of 2 to 20, and the grand mean on the 10 item subtest of new information was 4.31 with a range of 0 to 9. No student scored 100% on the entire test and the grand means were close to 50% on each test, so the tests were relatively difficult. The grand means, however, were not used in any other analysis of the data.

Table 1
Means, Standard Deviations, and Sample Sizes

Treatment	Total Test		Subtests: Previously Tested		Subtests: New Information	
	Mean	*SD*	Mean	*SD*	Mean	*SD*
Group A Multiple-Choice *n*=63	19.05	4.00	14.05	2.89	5.00	1.95
Group B Short-Answer *n*=64	16.86	4.72	12.48	3.28	4.38	2.03
Group C No Test Control *n*=60	13.85	4.57	10.33	3.14	3.52	1.97
Overall *n*=187	16.63	4.43	12.32	3.10	4.31	1.98

The GLM procedure was used to compare the 3 treatment groups (Group A, Multiple-choice Test; Group B, Short-answer Test; and Group C, Control) on the means of the total delayed retention test scores. A significant difference was found among the total test means: $F(2, 184) = 21.16$, $p<.0001$, *R-Square* = .19.

Following this significant finding, the GLM procedure was again employed to examine the means of each subtest. Significant differences were found among the means on the subtest of previously tested information, $F(2, 184) = 22.07$, $p<.0001$, *R-Square* = .19, and among the means on the subtest of new information, $F(2, 184) = 8.64$, $p<.0003$, *R-Square* = .08.

Followup comparisons were conducted via *t*-test (LSD) procedures in SAS. The results of the LSD comparisons are shown in Table 2. The critical value used was $t(184) = 1.97$, $p<.05$. In the total test scores and both subtests (previously tested and new information), the means of the two treatment groups which were previously tested, Group A (Multiple-choice Test) and Group B (Short-answer Test) were both significantly greater than the means of Group C (No Test Control).

Table 2
Contrasts of Group Means Via LSD Procedures

	Groups and Means		
	Group C No Test	Group B Short-Answer	Group A Mult.-Choice
Total Test	13.85	16.86	19.05
Subtests:			
Previously Tested	10.33	12.48	14.05
New Information	3.52	4.38	5.00

Note. Means *not* underlined were significantly lower at the .05 level.

LSD followup comparisons also showed that Groups A and B were equal in their retention knowledge of the new information (10 item subtest of information which was not previously tested), but that Group A (Multiple-choice Test) outscored Group B (Short-answer Test) significantly on the 20 item subtest of previously tested information and on the total test.

Discussion

The first of three research questions addressed by this study was: If delayed retention learning is the objective of instruction, does initial testing of the information aid retention learning? Within the constraints of this study, testing of instructional material did promote retention learning. Two types of tests were shown to be effective in supporting retention learning. The question could be raised whether it was the actual act of taking the test which aided retention learning or if the knowledge that a test was forthcoming motivated students to study more effectively. This was a central research question of a previous study (Haynie, 1990a) in which announcements of the intention to test were evaluated and shown not to be effective in promoting retention learning unless they were actually followed by tests or reviews. No attempt was made in this study to separate the effectiveness of prior knowledge concerning upcoming tests from gains made while studying for and taking the tests.

The second research question was: Does initial testing by short-answer tests aid retention learning as effectively as initial testing with multiple-choice tests? The findings presented here provide evidence that multiple-choice tests promote retention learning more effectively than do short-answer tests. Both Group A and Group B scored significantly higher than the control (no test) group on the total test and both subtests. However, multiple-choice tests appear to be more effective in promoting retention learning than are short-answer tests as shown by the finding of significantly higher scores for Group A on the subtest of previously tested information. This may be because the correct answer to each item is provided along with the distractors in the multiple-choice items, but students had no cues to help them remember the answers, or even reconsider the issues, in the short-answer test items. Moving information from short term to long term memory is aided by rehearsal and, it appears that, multiple-choice test items are a more effective form of rehearsal than short-answer test items.

An alternate conclusion would be that the students who took the multiple-choice test performed better simply because the delayed retention test was in the same (multiple-choice) form. Further research should be conducted to examine this factor. The recommendation given here is to choose the type of test which is best suited to the educational objectives and trust that when it is used for evaluation, it will also aid in promotion of retention learning. However, if it is desirable to maximize the promotion of retention learning, then use of multiple-choice items on the test may be preferred over short-answer items. This does assume, however, that the multiple-choice items used will be good test items which are devoid of the errors in item developement shown in previous research on test items authored by teachers (Haynie, 1992).

The final research question was: Will information which is not represented on initial testing be learned equally well by students tested via short-answer and multiple-choice tests? The delayed retention test used in this experiment contained a subtest of ten items interspersed throughout the test which had not appeared in any form on the initial tests. If the two types of test were equal in effectiveness, then both the subtests of new and of pretested information should have found no differences between the groups except for poorer performance by the control group. Alternatively, if one type of test were superior in promotion of retention learning, then one experimental group should outscore the other one on the subtest of previously tested material, but not on the subtest of new material.

Although the tests were short, there was no significant difference in the performance of the two previously tested groups on the ten item subtest of new information. Though both of these groups outscored the control (no test) group significantly on this subtest of novel information, there was no difference between the two experimental groups. So, short-answer and multiple-choice tests were both equally effective in promotion of retention of information which was studied but which was not actually reflected in the test items. The conclusion here is, if short-answer tests are well suited to the type of learning objectives being tested from an evaluation viewpoint, then well developed short-answer tests should be equally effective in promoting retention learning of incidental information as multiple-choice tests.

Recommendations

Since testing requires considerable amounts of student and teacher time in the schools, it is important to maximize every aspect of the evaluation process. The ability of teachers to develop and use tests effectively has been called into question recently, however, most research on testing has dealt with standardized tests. The whole process of producing, using, and evaluating teacher-made tests is in need of research.

This study was limited to one educational setting. It used learning materials and tests designed to teach and evaluate a limited number of specified objectives concerning one body of subject matter. The sample used in this study may have been unique for unknown reasons. Therefore, studies similar in design which use different materials and are conducted with different populations will be needed to achieve more definite answers to these research questions. However, on the basis of this one study, it is recommended that: (a) when useful for evaluation purposes, classroom testing should continue to be employed due to its positive effect on retention learning; (b) both multiple-choice and short-answer tests promote retention learning, however, multiple-choice tests are more effective in this regard; (c) it appears that teachers who use short answer tests need not be overly concerned that students will only benefit from the learning of those specific facts represented on the test to the exclusion of information not represented because both short-answer and multiple-choice tests were shown to be equal in their ability to promote retention of material which was studied but not actually included on the test. So, if the instructor wishes to maximize the potential gains in retention made while students take a test, multiple-choice tests should be used, however, if short-answer tests are more appropriate for the evaluation situation present, their use will also benefit students' retention, although to a lesser degree. The ability of the individual instructor to develop good multiple-choice test items should be considered in making this decision.

Short-answer tests may have advantages of their own which make them useful in some situations because they do not force students to choose from a predetermined set of responses. Though some of the research examined in the review of literature for this study was critical of short-answer tests, the fact that teachers have difficulty authoring effective multiple-choice items may make short-answer items a better choice for many situations. This study did not examine the effect of post test reviews when using short-answer tests. Such reviews have been shown to be helpful in promoting retention of information tested via multiple-choice tests. The effects (on retention) of post test reviews following short-answer tests should be addressed in future research.

Testing, pre test reviewing, post test reviewing, and occasional retesting require large amounts of learning time. As technology education moves away from the traditional "shop" setting of industrial arts and toward a more conceptually based curriculum, the teaching and testing of cognitive information increases in importance. More of the time of students and teachers will be consumed by testing and related activities such as pre and post test reviews. Technology teachers should understand how to make this time beneficial for learning as well as for evaluation. Technology teacher educators should help preservice and inservice teachers learn how to maximize the learning potential of time devoted to testing and reviews. The value of tests in promoting retention learning has been demonstrated here and two research questions about the types of tests to use for specific purposes within the context of technology education classes have been addressed, however, there remain many more potential questions about all sorts of teacher-made tests. The tests used in this study were carefully developed to resemble and perform similarly to teacher-made tests in most regards, however, there are still research questions which must be answered only on the basis of tests actually produced by teachers and for use in their natural settings. The process of pre-test reviewing, testing, and post test reviewing is too time consuming to be ignored. Continued research must be conducted to determine the best ways to test and review so as to meet the needs of evaluation and to maximize retention of important learning in technology education and in other disciplines.

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Diderot, the Mechanical Arts, and the *Encyclopédie*: In Search of the Heritage of Technology Education

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In a recent symposium on critical issues in technology education, Walter Waetjen (1992) regretted the lack of a history of technology education (pp. 25; 28). This paper contributes to a history of technology education by focusing on one of the most ambitious attempts in early modern history to describe technological knowledge — Diderot's *Encyclopédie* (Diderot & d'Alembert, 1751-1772).[1] In Diderot's time, the idea of representing technological topics was not new, but Diderot's *Encyclopédie* was distinctive in several ways.[2] It was written and illustrated profusely by many contributors, numbering well over one hun-

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[1]Diderot's *Encyclopédie* has stimulated much commentary but there are some critical secondary works. Two of Darnton's works (1979, 1984) orient the reader to the social and publishing context. The compilations of Schwab (e.g., 1984) as part of the Voltaire Foundation series are indispensable for finding one's way around the *Encyclopédie*. Kafker (1981) distinguishes Diderot's approach from the other encyclopedias of the period, such as Johann Heinrich Zedler's much larger, though less illustrated *Universal Lexicon*, Gianfrancesco Pivati's *Nuovo dizionario*, John Harris' *Lexicon technicum*, and Ephraim Chambers' *Cyclopaedia*. More recently, Kafker and Kafker (1988) published an inventory of Diderot's known contributors.

The *Encyclopédie* was published as a subscription series from 1751 to 1772. It appeared at the rate of one letterpress volume per year from 1751 to 1757 when its royal privilege was revoked. The writing continued on a clandestine basis, but Diderot's focus shifted to the plates which were less controversial. The final 10 letterpress volumes bear the date 1765; the plates were published in the 1760s and early 1770s.

An important, though less known, French contemporary work was the extensive government-funded project on the mechanical arts directed by Réaumur of the Académie des Sciences (1761-1789). Indeed, Diderot was accused of plagiarism because he used some of their documents. (Regarding this controversy, see, e.g., Berthier, 1752; Huard, 1952.) But the Académie's work was slower to be published, it was more specialized in scope, it was not part of a larger integrative work of the sciences and liberal arts, and it never achieved the same degree of notoriety. Diderot criticized it indirectly in his article ENCYCLOPÉDIE, Vol. 5, p. 647) for its inaccessibility.

[2]Space does not permit a review of the history of texts on the mechanical arts and classifications of such knowledge prior to the *Encyclopédie*. An extensive bibliography of patristic and classical texts can be found in Whitney (1990), who focused on scholarly interpretations of the mechanical arts in antiquity and the Middle Ages. But Diderot and his contributors were interested in the more practical aspects of describing technological knowledge. It is Diderot's focus on developing a framework for describing and illustrating as many of the mechanical arts as possible that distinguishes Diderot's work. See Pannabecker (1992) for a study of two of Diderot's craftsmen contributors to the *Encyclopédie*.

dred authors for the 17 folio letterpress volumes alone. A large proportion of the approximately 2,900 plates in 11 folio volumes were devoted to technology. The trying circumstances of its publication and political censorship contributed to its notoriety, later editions, and its widespread circulation. It remains one of the most accessible primary sources for the study of technology during the Enlightenment because of later reprints and its detailed illustrations.

The *Encyclopédie* is important in the heritage of technology education because it popularized the major shift from viewing the mechanical arts as embedded in the minds and shops of craftsmen to a systematic written and pictorial representation of the mechanical arts. Well-known cases of systematic teaching in the mechanical arts such as the Russian system of tool instruction have their rationalist roots in representations such as those of the *Encyclopédie*.

Purpose

The main purpose of this paper is to show what Diderot considered critical in systematizing and representing the mechanical arts in two-dimensional form. In so doing, he left an important heritage for our understanding of the development of technology, especially the ways it has been organized and represented for the purposes of dissemination. It is in examining such historical precedents that technology educators today can gain a better understanding of how the historical "packaging" of technology has influenced our own educational "delivery systems."

Some attempt will be made to show parallels between Diderot's concerns, problems, and frustrations and those faced by technology educators today. But the central focus remains Diderot's approach to representing the mechanical arts. Inquiry into the heritage of technology education needs to be conducted with due respect for the historiographical controversy of drawing connections between the past and present. In this respect, even terms can be problematic. For example, the term "technology" was rarely used in the eighteenth century; the term "mechanical arts" encompassed an important part, though not all of what we now call "technology." Thus, the occasional use of "technology" here is intended to bridge the gap for modern readers while retaining respect for the differences of the past.

The first section examines the historical context in which Diderot and his writers produced the *Encyclopédie*. The main section describes Diderot's work and four issues that are pertinent to the heritage of technology education: (a) conceptual framework; (b) systematic method of analysis and description; (c) theory and practice; and (d) technology and society.

Background

In the late 1740s to the 1760s, Denis Diderot (1713-1784) worked tirelessly to conceptualize and represent knowledge collected from craft communities, private and state industry, and existing documents to create a systematic understanding of the mechanical arts. But Diderot also emphasized the integration of the mechanical arts with the liberal arts and sciences. Darnton, a leading historian of French culture, noted that it was the mechanical arts that "constituted the most extensive and original part of the *Encyclopédie* itself" (1984, p. 198).

Historiographical Considerations

Diderot's role in stimulating interest in the mechanical arts is well known among historians of technology (e.g., Gille, 1952; Gillispie, 1958). However, in the United States, the historical awareness of technology education is still heavily influenced by works such as Bennett (1926, 1937) and Martin and Luetkemeyer (1979), which preceded the shift from industrial arts to technology education in the early 1980s. Neither Bennett nor Martin and Luetkemeyer examined Diderot's work.

While Bennett (1926) discussed Joseph Moxon's rationalist treatment of mechanical processes in the late seventeenth century (pp. 51-60), he tended to emphasize human development theories and institutional history. In his second volume, he examined the Russian system of tool instruction, emphasizing its systematic analysis of tool processes (Bennett, 1937, pp. 13-52; Pannabecker, 1986). The result is a shallow view of systematic analyses of the mechanical arts in the seventeenth and eighteenth centuries. It was during this period that Diderot constructed a systematic view of the mechanical arts.

Denis Diderot as Editor and the Publishing Venture

Diderot had grown up around craftsmen and their work because his father was a master cutler, but he did not pursue his father's trade. Diderot acquired a classical education at a school in Langres until he was 15 years old and then high school in Paris for three years (Crocker, 1966). Although his father was well off financially, he did not support his son's interest in philosophy and writing. Hence, the young Diderot was constantly in and out of debt, drifting from job to job until he landed his position as editor of the project that would eventually become the *Encyclopédie*.

It was in the late 1740s that Diderot and Jean d'Alembert, a respected mathematician, were selected as co-editors of the French translation of Chambers' *Cyclopaedia, or Universal Dictionary of the Arts and Sciences,* one of the learned compilations of eighteenth-century England. Before long, Diderot and d'Alembert found Chambers' work to be woefully inadequate and they proposed to the publishers a greatly expanded work. (Jean d'Alembert eventually withdrew from his duties, thus leaving the major responsibilities to Diderot.)

By the middle of the eighteenth century, the Parisian private publishing industry had the financial potential and interest in supporting such a large multivolume work. The middle and upper classes were interested in new, controversial ideas and the government was generally tolerant, provided one remained within accepted ideological limits, which Diderot did not. Indeed, the subsequent notoriety of the *Encyclopédie* was due, in part, to many highly controversial articles, especially on religious, political, and economic topics. In the late 1750s, controversy reached such levels that the *Encyclopédie*'s license for publication was revoked until sufficient political protection could be negotiated for its continued publication.

Originally sold by subscription, the *Encyclopédie* went through several editions amounting to around 25,000 copies by 1789 distributed around Europe and other continents (Darnton, 1979, p. 37). One Swiss publisher contacted Benjamin Franklin about a distribution center in America which, however, was never established. Thomas Jefferson promoted its diffusion in America: he bought a Lucca edition for public use for 15,068 pounds of tobacco and a personal copy when serving as American minister to France (Darnton, 1979, p. 318).

Mechanical Arts, Technological Progess, and Economics

The description of the mechanical arts in the *Encyclopédie* was not in itself very controversial. But the public climate towards publishing knowledge about the mechanical arts was ambivalent. Mercantilist ideas still dominated economic thought, holding that the amount of wealth in the world was fixed and each country competed to amass as much bullion as possible, especially through exportation of finished goods. Many persons considered it best to maintain secrecy over knowledge of the mechanical arts, especially the most advanced and those geared to luxury trades.

It was in this climate that Diderot proposed to systematize, describe, and publish knowledge of all the mechanical arts, thus promoting a new ideology of wide and open diffusion of the arts. According to Proust (1967), Diderot had three main goals in regard to technology: (a) to reach a large public; (b) to encourage research at all stages of production; and (c) to publish all the secrets of manufacturing (p. 205).

The *Encyclopédie* contributed to the gradual shift from mercantilist attitudes towards more liberal economic views, of which certain elements of change were already underway. (See, e.g., Meyssonnier, 1989, for a discussion of early liberal economic views.) The idea of economic progress was closely linked to the development of liberal attitudes towards reduced state control of industry and commerce.

Diderot's resources were limited, however, and the *Encyclopédie* often did not present the most advanced technology of the time. Indeed, much of what it described was typical of the late seventeenth and early eighteenth centuries. (For a discussion of this issue, see, e.g., Gille, 1952; Mousnier, 1958; and

Proust, 1967.) Nevertheless, Diderot sought to promote an ideology of progress, undermine craft guild control of knowledge, and encourage technical research, especially in regard to better quality materials, production speed, and better products (ART, Vol. 1, p. 717).[3]

The *Encyclopédie* and the Mechanical Arts

In the early years of the project, Diderot reflected on its development process, for example, in his "Prospectus" in 1750, which articulated the conceptual framework. Later, he reflected on the mechanical arts in ART, an article published in the first volume of text in June 1751 and in ENCYCLOPÉDIE, an article published in the fifth volume of text in November 1755. Diderot struggled with various issues and problems, some of which afflict curriculum development projects in technology education today. Four of these issues are discussed below.

Conceptual Framework: Integrating Knowledge

In the "Preliminary Discourse" to the *Encyclopédie* and the "Prospectus," d'Alembert and Diderot acknowledged the philosophers who influenced the conceptualization of their project. Of these predecessors, Francis Bacon and John Locke stood out, especially in regard to the mechanical arts. (For a brief introduction in English to the conceptual framework used in the *Encyclopédie*, see Darnton, 1984, pp. 190-213).

Some of Diderot's philosophy of the mechanical arts followed the reasoning of Bacon and Locke, especially on developing a common language and graphic representation that related words to things through pictorial images. Locke had written in 1689 about the importance of a general dictionary of things and words, though he thought it would probably be too time consuming and expensive (Locke, 1952, p. 306). (Such an integrated language has been critical to systematizing technology and education.) But Diderot and d'Alembert went beyond Bacon and Locke by implementing their ideas in a comprehensive work. The three main human faculties, borrowed from Bacon, were memory, reason, and imagination. These three faculties corresponded to the knowledge divisions of history, philosophy, and poetry respectively. Most of the mechanical arts were classified under the human faculty of memory as part of the division of history "Prospectus."

The sequence of the entries in the *Encyclopédie* followed alphabetical order, but the division of knowledge was usually given in parentheses at the beginning of the article. In addition, cross-references to related topics were often

[3]References to the *Encyclopédie* are the author's translation unless otherwise noted. Articles are cited in capital letters, followed by volume; plates and commentaries are cited according to the volume of the plate. Citations including the "Prospectus" (Vol. 1) are from Diderot and d'Alembert (1751-1772).

given in the text. This system of connecting entries and relating them to the broader system of knowledge was complex and lacked consistency, however, and the alphabetical system dominated organization (Schwab, 1984, p. 15).

Method of Analysis and Description of the Mechanical Arts

The method of describing each mechanical art grew out of Diderot's concept of a science, which he viewed as “a system of rules or facts relative to a certain object” (“Prospectus,” p. xxxvij). In order to organize knowledge of the mechanical arts, Diderot outlined in the “Prospectus” (p. xxxix) a framework which was simple in appearance and presumably applicable to all the mechanical arts.

> Here is the method we have followed for each art and craft. We treated the following questions:
> 1. The materials and the places where they are found, the manner in which they are prepared, their good and bad qualities, the different kinds available, the required processing before and during their utilization.
> 2. The main products that are made with them and how this is done.
> 3. We have supplied the names, descriptions, and diagrams of tools and machines, with their parts when taken apart and assembled; the section of certain molds and other instruments if it is appropriate to know about the interior design, their contours, etc.
> 4. We have explained and represented the workmanship and the principal operations in one or several plates where sometimes only the hands of the craftsman can be seen and sometimes the entire craftsman in action, working at the most important task in his art or trade.
> 5. We have collected and defined in the most accurate way possible the terms that are peculiar to a given art or trade. (Gendzier, 1967, pp. 39-40)

In the letterpress volumes, each craft was described in a major article such as glassmaking, ironworking, or tanning. In addition, important technical terms had separate entries, which were published in alphabetical order. In principle, each major article in the text was complemented by a series of illustrations (copperplate etchings) and a commentary in the volumes of plates. (See Figure 1.) Ideally, the article was to refer to the objects depicted in the plates by a system of code numbers and letters, thus integrating texts and images; however, there was considerable variation among contributors in their use of this method.

The first plate for each craft usually depicted an overview of the shop or a part of the shop. Subsequent plates presented greater detail. Diderot emphasized the representation of machines, moving from the simple to the complex, sometimes going from knowledge of the workmanship to that of the

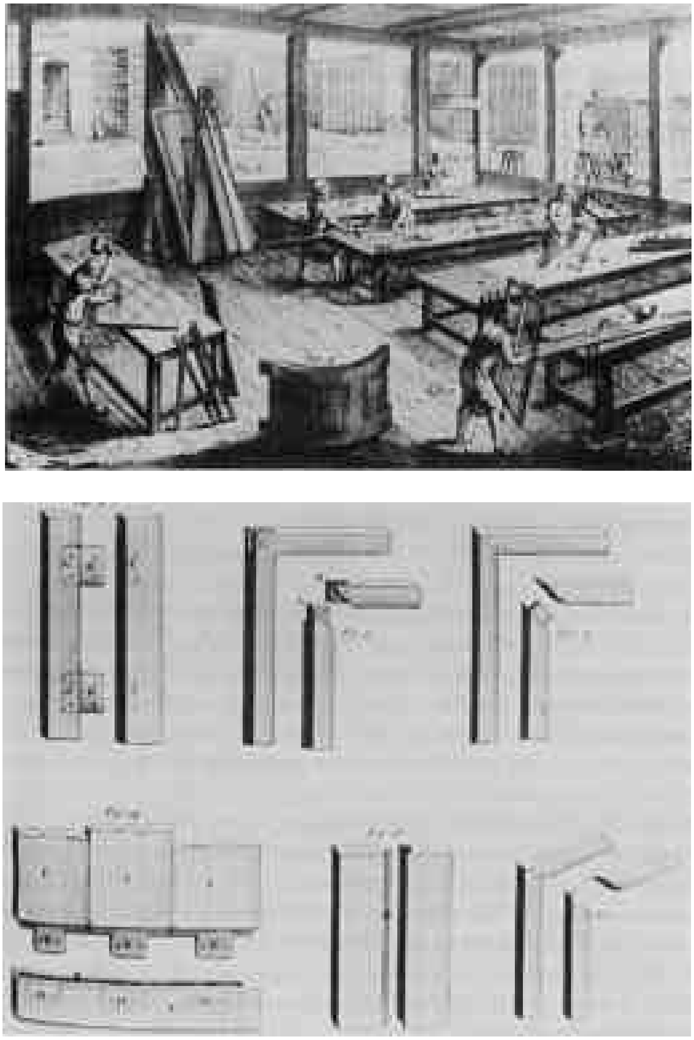

Figure 1. This plate (45% reduction) is the second in a series of 38 plates on joinery in construction. It shows various operations such as sawing and drilling. Note the detailed wood joints illustrated in the lower portion of the plate. The plate was designed by Lucotte and executed by Defehrt (Menuisier en Batimens, Vol. 7). (Courtesy Special Collections Department, Kansas State University Libraries, Manhattan, KS)

machine and other times from knowledge of the machine to that of the work itself (“Prospectus,” p. xl).

A superficial reading of Diderot's system and exposure to the plates suggest an impressive coverage of the mechanical arts. He proposes to discuss the materials and their initial processing, major products, detailed analysis of tools and machines, workmanship of the craftsmen, and terminology. This system is not unlike that used by contemporary texts in the twentieth century and indeed still impresses contemporary readers.

Yet every method of representation has its own emphases and limitations. In Diderot's method, for example, four out of the five points were impersonal; only the fourth point (workmanship of the craftsmen) even mentioned craftsmen. Thus, Diderot's emphasis was on physical objects and processes, which would now be considered a fairly low level understanding of the mechanical arts or technology. Higher levels such as intuitive knowledge, experimentation, perceptual skills, problem-solving, or the analysis of conflicting or alternate technical approaches were scarcely recognized in Diderot's system. Yet as he began to apply his system to the various mechanical arts, he came face to face with the complexities of theory and practice.

Theory and Practice

The dualism of theory (or “speculation” as Diderot called it) and practice was a recurrent theme in Diderot's writing. But this theme was complicated by the fact that Diderot's interests operated at two levels: (a) the level of representing the arts in language and drawings and (b) the level of the arts themselves. The constraints of Diderot's role as editor reinforced his preoccupation with representing the arts, but he still maintained an interest in the practice of the arts.

For example, he had no illusions about people becoming craftsmen simply by reading books. “It is handicraft which makes the artist, and it is not in Books that one can learn to manipulate” (“Prospectus,” p. xl). This concern helps to understand his critique of Chambers who “read books but he hardly ever saw artists; however, there are many things that one learns only in the shops” (p. xxxv). Diderot claimed that he and his contributors visited the shops, questioned the artisans and took dictations from them, developed their thoughts, and organized terms and facts into tables (p. xxxix). (See Proust, 1967, however, for a realistic evaluation of the extent to which Diderot immersed himself in the shops, which was probably quite minimal, pp. 192-195).

Apparently as a result of these visits, Diderot concluded that “most of those who perform the mechanical Arts have taken them up by necessity, & work only by instinct. We can hardly find one dozen out of a thousand capable of explaining clearly the instruments they use and the products they make” (“Prospectus,” p. xxxix). His experiences led him to express his editorial role as "the painful and delicate function of helping to give birth to their minds [or spirits], obstetrix animorum" ("Prospectus," p. xxxix).

Thus Diderot sought to find exceptional people who could both understand thoroughly each art and describe it. According to him, one writer did not seem to know enough about his subject matter; another only grazed the surface, treating the material more as a man of letters than as an artisan; and a third produced a richer text which was more the work of an artisan, but which was too short, with little detail on machines and operations ("Prospectus," p. xxxix). But he also acknowledged that space limitations imposed by his publication necessitated limiting the extent of detail ("Prospectus," p. xl).

In 1751, Diderot explicitly took up the matter of theory and practice in his article ART. He recognized the interdependence of speculation and practice but considered speculation to be the "inoperative knowledge of the rules of the Art" and its practice to be "only the habitual and non-reflective usage of the same rules" (ART, Vol. 1, p. 714). Thus Diderot tended to neglect the complexity of reflective practice so crucial to experimentation, problem-solving, and development, even though he explicitly promoted research and development.

Indeed, Diderot's craft was writing, not practicing one of the mechanical arts, and his work reflects this preoccupation. His "method" was primarily a theory of representation. But sometimes in the practice of writing and illustrating, Diderot's contributors strayed from his method, sometimes describing their art in greater depth than his method demanded. For example, Pannabecker (1992) has shown how Brullé, a printing shop foreman and contributor of the article on letterpress printing, went farther than Diderot's method of representation by attempting to describe some aspects of intuitive knowledge, alternate practices, and technical problems.

Diderot also compared the representation of the mechanical arts to the reporting of scientific work by scientists. In his article ENCYCLOPÉDIE, he noted that scientists wrote and argued about their work, thus promoting its advancement (Vol. 5, p. 647). Artisans, according to Diderot, lived in isolation and obscurity. Systematizing and writing about the mechanical arts would bring to light their hidden ideas, thus providing an account of experience for theoretical reflection.

Diderot, like technology educators today, struggled with the melding of theory and practice. While it may be easy to criticize him in retrospect for the limitations of his descriptive method, his preoccupation with representation, or his views of theory and practice, he did help bring to light both theoretical and practical considerations that would become crucial to disseminating knowledge of the mechanical arts in written and graphic form.

Technology and Society: Reconstructing Society

Diderot wanted to change society because he thought that the distinction between the liberal and mechanical arts, though well-founded, had produced a “bad effect in degrading very respectable and useful people” and neglecting the careful study of the mechanical arts (ART, Vol. 1, p. 714). From this position he sought to rebalance the relationship of the mechanical arts in society, a recurrent theme also found in the “Prospectus” and in the article ENCYCLOPÉDIE (Vol. 5).

His method for promoting social change was through language, pictorial images, and the structuring of knowledge. Written and pictorial knowledge of the mechanical arts was not widely accessible in a single work and most of the mechanical arts were taught in the context of shops. Diderot's project departed from this status quo and popularized the notion that the mechanical arts could be represented as separable from people. This notion would become pivotal for education because the knowledge became less of a secret and more transmittable in other contexts, such as books and schools.

Diderot, through language and alphabetizing all areas of knowledge, thus contributed to a new ordering of society in which the literate would have greater access to some knowledge of the mechanical arts. Koepp (1986), for example, has taken this argument to the extreme, concluding that the *Encyclopédie* was a “subtle and comprehensive expropriation” of nonliterate knowledge and power from workers by the literate culture (p. 257). This is only partially true, however, since the knowledge that they gained access to was limited to what the writers managed to represent. The deeper layers of intuition, perceptual discernment, manipulative skills, and heuristics were, at best, only partially represented in the *Encyclopédie*.

This limited representation of the mechanical arts was due in part to the fact that many of Diderot's writers were not specialized in the craft that they were describing. For example, his chief assistant Louis-Jacques Goussier designed many of the plates and seemed to either share or accept Diderot's emphasis on the physical or non-human elements of the mechanical arts. Yet, Diderot expressed his frustrations at trying to enter the deeper layers of technical culture. In 1755, he criticized artisans who suspected any curious person who asked them questions of being a tax collector or worker wanting to set up a competing shop (ENCYCLOPÉDIE, Vol. 5, p. 647). For Diderot, the artisans were at times so impenetrable that he suggested that the fastest way of learning would be to enter into apprenticeship or send a secret representative. But he recognized that some groups with higher status such as academicians also preferred to keep this knowledge secret, in order to maintain the nation's economic advantage (ENCYCLOPÉDIE, p. 647). Despite Diderot's awareness of the complexity of the social attitudes of different groups towards his work on the arts, it is the rational, technical emphasis that dominates his legacy of the mechanical arts.

Conclusion

Through the *Encyclopédie,* Diderot attempted to disseminate specialized knowledge in the mechanical arts organized by his own rational method. Furthermore, he included this knowledge in his "general system of human knowledge" (ENCYCLOPÉDIE, Vol. 5, p. 643A), but he did not achieve an integrated view of the mechanical arts and society. His legacy, which has influenced subsequent representations of technology, is a challenge for technology educators as they seek to teach the integration of technology and society while avoiding such a single-model ideology.

Paradoxically, Diderot sought to improve the status of artisans and the mechanical arts by exposing their work and knowledge, but his unified system of representation neglected the social aspects of their culture and some of the most complex forms of knowledge in the arts. The neglect of the social aspects of the arts is heightened by the dominance of the plates, which constituted a spectacular part of his rational method. In addition, viewers have typically neglected the accompanying descriptions and related articles in the letterpress volumes. This superficial exposure has, in a sense, reinforced Diderot's emphasis on what can be most easily represented: materials, products, machines, and operations.

Diderot's method obscured aspects of the arts or technology that are difficult to articulate, analyze, or draw: technical problems, intuition, design failures, experimentation, and human curiosity and creativity, all of which are critical for invention and innovation. Although Diderot claimed to be interested in invention and innovation, his burdensome duties as editor left him little time to pursue such matters. Instead, he established a method connecting language, concepts, and objects for the purposes of communication and dissemination.

Yet Diderot also left a record of his own curiosity and a convincing statement of the importance and complexity of the arts. He reminded readers that "Bacon regarded the history of the mechanical Arts as the most important branch of true Philosophy" (ART, Vol. 1, p. 714). Diderot also recognized the importance of integrating scientific knowledge with the mechanical arts. In his role as editor, he noted the necessity of a strong background in natural history, mineralogy, mechanics, rational and experimental physics, and chemistry in order to understand the arts. In establishing a systematic method of representing the mechanical arts, organizing contributors to utilize his method, and relating the arts to other forms of knowledge, Diderot left an enduring legacy for the heritage of technology education.

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Establishing a Taxonometric Structure for the Study of Biotechnology in Secondary School Technology Education

John G. Wells[1]

Traditional biotechnology was a part of human history long before the realization of its mechanics. Historically it has been an integral part of the human social structure, continually changing the shape and visage of our society. The change has been progressive, with a pervasiveness that insures its lasting inclusion in every aspect of our daily existence. The advent of a *modern* biotechnology revolution was sparked less than twenty years ago, and was clearly underway at the onset of this decade. Current developments in biotechnology are proceeding at accelerated rates similar to those seen in the microelectronics boom of the 1970s.

Modern biotechnology is a technology with enormous potential that will involve extensive research and development throughout the 1990s. During the next few decades advances in biotechnology will require individuals associated with the biotechnology industries to receive specific education and training, and in addition, will result in the need for increased public awareness of its potential benefits and negative consequences. New scientific knowledge, and the appropriate technologies accompanying it, cannot take root and be purposefully controlled in the absence of an informed public. Those in education, both in this country and abroad, have begun to realize the enormous potential biotechnology will have for influencing our future lives, and are beginning to address the need for its inclusion in secondary curricula (Royal Society, 1982; Gayford, 1987; Project 2061 Panel Report, 1989; Wise, Buonopane, and Blackman, 1990). However, these initial attempts are taking place largely in the hard sciences (i.e. chemistry and biology) and engineering. There is a danger in directing such instruction at a narrow segment of the student population. That which serves the specialists does not necessarily fit the needs of the majority. In particular for biotechnology, a broad scientific and technological education is required that fits the overall goals of general education.

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The increased attention currently being given to biotechnological advances has brought with it an increased understanding of the technical aspects inherent in the various biotechnical processes. In light of this, contemporary professionals in technology education are recognizing that biotechnology has a natural place within their general education curricula, and must be made part of the instructional program (Wittich, 1990). Recently strong support for this move was presented in *A Conceptual Framework for Technology Education* (Savage and Sterry, 1991). The foundation of this new document incorporates many of the concepts used in the *Jackson's Mill Industrial Arts Curriculum Theory* document (Snyder and Hales, 1981), and suggests, as did the first document, a model for the development of a technology education course of study. The model specifically points to the need for development and inclusion of biotechnology in technology education instruction (Savage and Sterry, 1991), and ultimately recommends it as a fourth content organizer, along with transportation, production, and communication.

The technology education profession has come to recognize the importance of including biotechnology within its discipline, and is poised to put forth the efforts required to do so. They are in line with those other professions in education involved with developing curricula for biotechnology. Requisite of this however, will be the development of a structure from which biotechnology content is derived and made deliverable within an instructional setting. Such development inherently precludes serious consideration of new content within a discipline. However, fundamental to the development of any biotechnology curricula or instructional program is agreement on a content structure and those seminal elements that comprise it. Lacking from those professions involved with biotechnology instruction is the research-based determination of a structure from which the content is derived.

Purpose

This research was performed in response to the absence of an agreed upon curriculum structure for incorporating instruction in biotechnology at the secondary level. The purpose of this study was to develop a conceptual model of the first two hierarchical levels of a biotechnology taxonometric structure. Specifically, such a taxonomy, derived through expert consensus, would allow for future development of secondary biotechnology curriculum, applicable both within a technology education program or biological sciences program. To this end the following research question was addressed in this study:

1. To what degree can consensus be reached, through a panel of experts, on the primary components of a biotechnology taxonometric structure for the secondary school level?

Methodology

For this study, and eventual use at the secondary education level, the term *biotechnology*, taking into account both traditional and modern techniques, is defined as:

> ...any technique that uses living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop micro-organisms for specific uses (Office of Technology Assessment, 1988, 1991; Federal Coordinating Council for Science, Engineering, and Technology, 1992).

The research method used in this study was the Delphi technique. The fundamental purpose of this technique is to obtain a consensus of opinions from a panel of experts, and was seen as an appropriate initial procedure for determining instructional content. Four sources were identified from which prospective panel members would be chosen. The sources identified were (a) major biotechnology companies; (b) educational organizations associated with science and technology; (c) government agencies associated with science and technology; and (d) universities with major biotechnology departments. From each of the four sources a pool of individuals was sought, from which a total of twenty would be randomly selected. The initial size of the entire pool of potential participants was 151 individuals, with selection based on a pre-determined set of criteria for identifying experts. Five individuals from within each of the four sources were selected at random, culminating in a total of 20 potential panel members. The resultant 20 member panel of biotechnology experts was evenly split between 10 males and 10 females. This split was a purely random occurrence.

This study used three instruments that are identifiable as Delphi I, Delphi II and Delphi III. A three round Delphi sequence is considered ideal, as it has been shown to take into account virtually all (99%) of the changes in respondent opinions by the end of the third round (Martino, 1975; Weatherman and Swenson, 1974).

The instrument used for Delphi I was developed as an unstructured, characteristic-retaining variation of the model Delphi approach. Initiating the study with a delimiting context is a variation on the classic Delphi method, supported through research conducted by Martino (1975). A modification of this type calls for an abstract to preface the first round instrument, providing the panelists with the context of the study as an informative measure. It is an adaptation however, in which the characteristics originally intended to eliminate disadvantages concurrent with committee problem-solving activities (i.e. anonymity, iteration with controlled feedback, and statistical group response), are maintained. The panel members used in this study all had expertise in, or related to, the field of biotechnology. However, considering the institutional diversity of these individuals, the potential existed for their viewpoints to differ drastically. Hence there was a need for the modification in order to present a common information base with round one, that provided the members with an initial context reference point from which to view the issue.

Consequently, a brief abstract clarifying the context within which to view biotechnology was included with the round one questionnaire packet. The abstract specified (a) the philosophical and instructional basis for technology education, (b) the targeted level of instruction, (c) the purpose of that instruction, and (d) the environment in which it would take place.

With a common contextual base established, the Delphi I questionnaire could then be presented in an unstructured, open-ended response format. Experts were requested to designate knowledge areas representing the *major* areas of biotechnology endeavor, and to then denote the subdivisions each area could be broken into as the next level in a structural hierarchy. In addition they were asked to give a brief rationale for their structure.

The hierarchies received from Delphi I were reviewed by a local committee composed of the technology education researcher and two local biotechnology experts, to identify unique biotechnology knowledge areas. Uniqueness was based on the following set of guiding principles, adapted from taxonometric studies in the technology education field (DeVore, 1966), to serve as selection criteria for a biotechnology taxonomy: (a) areas are mutually exclusive; (b) the word or phrase chosen delimits the area; (c) each area has a distinct universal concept that is inherent to the biotechnology knowledge base; (d) there is an internal relationship existing between areas; (e) the areas are universal, being international in scope and not bound by geographic or social boundaries.

Using this set of principles, biotechnology knowledge areas were derived by the local committee through an analysis of the titles and their associated subdivisions obtained from the returned Delphi I responses. Determination of these unique areas made possible the alignment of suggested subdivisions under the appropriate knowledge areas. The amalgamated structure became the basis for the Delphi II and III instruments.

In the second Delphi round experts were presented with the biotechnology knowledge areas that emerged from the first round responses. For each major area experts were asked to make judgments on the subdivisions listed below each knowledge area by rating them according to their degree of agreement or disagreement for inclusion in that particular biotechnology knowledge area. An eleven point scale ranging from 1 (not important) to 11 (critical) was used to rate the subdivisions. The higher the rating, the more the panel member indicated the subdivision was critical for thorough instruction in a given knowledge area. Space was also provided beneath each subdivision to allow respondents to give comment concerning their chosen rating score.

The returned scales were first examined for accuracy in following instructions. Scores assigned by the panelists were used to determine the 25th, 50th and 75th percentiles, and general descriptive statistics for each subdivision within all knowledge areas. Modal ratings for each item, and the respondent's rating position with regards to the mode, were incorporated into the third instrument mailed in the Delphi III packets.

In round three experts were provided with the results of the second round and asked to reexamine the scores on the scale report, with special consideration given to their position on a given item. They then had the option of adjusting their judgments or leaving them unchanged. Comments obtained from the Delphi II concerning specific subdivisions were included with the Delphi III instrument as a means of passive persuasion for individual panel member scores. This is congruent with Delphi methodology.

If a panelist with a response outside the consensus range (more than two points higher or lower than the modal rating) wished to leave the response unchanged, they were asked to state their reasons for not changing and include them with the Delphi III. Space was provided on the reverse side of each page for respondents to give comment. At the conclusion of this final review the panelists were instructed to return the scale report, with or without changes made.

The revised values assigned by the panelists in Delphi III were used to compute Q-values and median scores. Q-values, indicating the interquartile range, were computed for use as an indication of agreement among panel members on a given item. Consensus, as used in this study and supported through previous research (Thurstone, 1929; Copeland, 1977; Barnes, 1987; Croft, 1990), is defined as those items, rated on an eleven point scale, having Q-values equal to or smaller than 4.00. Items with Q-values larger than 4.00 indicate that experts have diverse opinions concerning their inclusion within a specific knowledge area. Those categories with calculated Q-values equal to or lower than four indicated strong agreement among experts concerning their inclusion.

In addition to ascertaining consensus, it was equally important to calculate an acceptability level for determining if an item should be included in a list of subdivisions considered important to biotechnology instruction. At the outset of this study experts in the field of biotechnology were requested to supply subdivisions they considered important to the study of biotechnology. As such, it was anticipated that the resultant lists would be composed of items initially bearing high importance. It followed then that ratings would be relatively high, necessitating a large range of acceptability. With the expectation of high item scores the 25th percentile was chosen as a suitable, lower end cut-off point for determining acceptance. A frequency distribution comprised of all median scores was constructed to locate the 25th percentile.

Results

The Delphi I instrument asked the twenty panel members for their response to two questions. The first question asked them to designate main biotechnology knowledge areas. Titles received from the Delphi I were initially grouped according to content similarities. For example, the titles "Genetic Engineering," "Genetics," and "Genetics & Genetic Engineering" submitted by three different panel members, were all placed within a single column because they represented a knowledge area of analogous characteristics.

Grouping of main knowledge areas was further refined by looking for similarities in subdivisions panel members chose to be included under a given title. For instance, the main knowledge area titles of "Traditional Biotechnology," "Microbiology," and "Microbial Applications" all contained subdivisions labeled fermentation, products of fermentation, fermentation technology, types of organisms, etc., and were therefore understood to be referring to similar processes, calling for all to be placed in the more general category of bioprocessing.

Nineteen of the twenty panel members (95%) returned a fully completed Delphi I instrument. An analysis of the data showed eight distinct biotechnology knowledge areas in the panel members' responses. Those eight knowledge areas, validated by the local committee, are shown in Table 1.

Table 1
Main Biotechnology Knowledge Areas

1.	Bioprocessing
2.	Foundations of Biotechnology
3.	Genetic Engineering
4.	Agriculture
5.	Biochemistry
6.	Medicine
7.	Environment
8.	Bioethics

A total of 446 unique subdivision titles were submitted by the panelists, from which a list of 84 primary titles was derived. The eight main knowledge areas and subdivision titles were used to construct the Delphi II instrument. This initial list of biotechnology knowledge areas and respective subdivisions can be found in Table 2.

The second round instrument asked panel members to rate the subdivisions, using an eleven point scale, with regard to the level of importance for their inclusion in the final taxonometric structure. Ratings by panel members for each of the eighty-four subdivisions were entered into a statistical file and calculations were made to determine the mode, median, and Q-value for each. Calculated median scores for all eighty-four subdivisions were used to construct a frequency distribution for locating the 25th percentile cut-off score. This cut-off score was determined to be 8.5. Thus, median scores for each subdivision equal to or greater than 8.5 were considered at a sufficient level of importance to be included in the taxonomy. Q-values were also calculated from the Delphi II data to determine the degree of consensus on the rating given to a subdivision. Table 2 contains a summary of Delphi II responses, listing the subdivisions by main knowledge area and rank ordered according to median scores.

Table 2
Summary of Delphi II Ratings

Rank	Knowledge Area & Subdivision	Mo	Mdn	Q
	BIOPROCESSING			
1	Fermentation	11	10.5	1.0
2	Culturing	10;11*	10.0	1.0
3	Microbial Applications	11	10.0	2.0
4	Genetic Engineering	11	10.0	2.0
5	Social Impact	11	10.0	5.0
6	Bio-Products	9	9.0	1.0
7	Types of Microorganisms	9	9.0	2.0
8	Separation & Purification Techniques	11	9.0	4.0
9	Microbial Structure	9	9.0	3.0
10	Processing Design: Monitoring & Growth	10	8.5	3.0
11	Biomass Conversions	8	8.0#	2.0
12	Bioprocessing of Fossil Fuels	8	8.0#	2.0
13	Processing Types	8	8.0#	2.0
14	Bioreactor Design	7	7.5#	3.0
15	Historical Overview	7	7.0#	3.0
16	Bioelectronics & Bioworks	5	6.5#	3.5
17	Packaging	1; 6*	5.5#	4.5
	FOUNDATIONS IN BIOTECHNOLOGY			
1	Laboratory Safety	11	10.0	1.0
2	Social Impact	11	11.0	2.0
3	Scientific Method	11	10.0	4.0
4	Definition of Biotechnology	11	9.0	5.0
5	Historical Background	8; 11*	8.5	3.0
6	Relevant Terms	9	8.5	4.0

Table 2 (cont.)
Summary of Delphi II Ratings

Rank	Knowledge Area & Subdivision	Mo	Mdn	Q
7	Career Information	9; 11*	8.5	4.0
8	Specifications on Lab Journals and Logs	8; 10*	8.0#	3.0
9	Career Preparation	8; 9*	7.5#	4.0
10	Profiles of Biotechnology Companies	5-9*	6.0#	3.0
	GENETIC ENGINEERING			
1	Genetic Code	11	11.0	1.0
2	Social Impact	11	11.0	3.0
3	Analysis of DNA	11	10.0	1.0
4	Vector Systems	10; 11*	10.0	1.0
5	Probing Techniques	10; 11*	10.0	2.0
6	Molecular Biology Techniques	11	10.0	2.0
7	Basic Structure of Genetic Material	11	10.0	2.0
8	Genetic Engineering Applications	11	10.0	2.0
9	History and Ethics	11	10.0	2.0
10	Basic Research	11	9.5	4.0
11	Basic Cell Structure	11	9.0	4.0
12	Genome Projects	10	9.0	4.0
13	Marine Biotechnology	7-10*	8.0#	3.0
	AGRICULTURE			
1	Tissue Culturing	11	10.5	2.0
2	Plant & Animal Genetic Engineering	11	10.0	2.0
3	Microbial Applications	10	10.0	1.0
4	Plant & Animal Applications	10	10.0	0.0
5	Social Impact	11	10.0	2.0
6	Plant Physiological Systems	11	9.5	3.0
7	Agrichemicals	10	9.0	3.0
8	Animal Physiological Systems	10	9.0	3.0
9	Food Safety	8	8.5	2.0
10	Aquaculture	10	8.5	3.0
11	Food Science	9	8.0#	3.0
12	Food Packaging	8	7.0#	3.0
	BIOCHEMISTRY			
1	Proteins	11	10.5	2.0
2	Enzymology	11	10.0	2.0
3	Control and Regulation	11	10.0	2.0
4	Methods of Analysis	10	10.0	3.0
5	The Genetic Material	10; 11*	10.0	2.0
6	Macromolecular Structure	11	9.5	3.0

Table 2 (cont.)
Summary of Delphi II Ratings

Rank	Knowledge Area & Subdivision	Mo	Mdn	Q
7	Social Impact	11	9.5	5.0
8	Carbohydrates	9	9.0	2.0
9	Lipids	8	8.5	2.0
	MEDICINE			
1	Social Impact	11	11.0	1.0
2	Immunology	11	10.0	2.0
3	Genetic Therapeutics	10	10.0	1.0
4	Molecular Medicine	11	10.0	2.0
5	Health Care Technologies	10	9.0	2.0
6	Medical Devices	8; 10*	8.0#	3.0
	ENVIRONMENT			
1	Social Impact	11	11.0	1.0
2	Biological Controls	10	10.0	2.0
3	Bioremediation	11	10.0	2.0
4	Biotreatment Systems	11	10.0	2.0
5	Biorestoration	10	10.0	1.0
6	Safety	10; 11*	10.0	3.0
7	Wildlife Management	8	8.0#	5.0
	BIOETHICS			
1	Social Impacts	11	11.0	1.0
2	Principles of Ethics	11	10.0	2.0
3	Impacts of Using Biotechnology	11	10.0	2.0
4	Regulation: Legislation & Safety	11	10.0	2.0
5	Potentials of Gene Therapy	11	10.0	2.0
6	Patenting of Life	11	9.5	3.0
7	Forensics	9	9.0	2.0
8	Technology Transfer	8; 10*	8.5	3.0
9	Population Studies	7	8.0#	2.0
10	Timetable for Development	4; 7; 8*	6.5#	4.0

*Multiple modal points #Median score below cut-off

The data gathered in the second round provided an initial indication of consensus concerning subdivision level of importance, leading to their eventual inclusion in, or exclusion from, the final taxonometric structure. These second round results showed a small portion of the subdivisions falling below the median cut-off point of 8.5. The seventeen subdivisions rated below the cut-off point for median scores are indicated in Table 2 by the “#” symbol next to the median score.

Delphi III was a modification of the second round instrument. Included in the third round instrument were additional components to allow panel members to (a) view their rating positions relative to the other experts, and to (b) adjust their previous rating if swayed by the majority response, or by arguments from the comments submitted by other panelists. Modal positions for each subdivision were circled on the Delphi III instrument to indicate majority opinion, giving panel members a reference point for their ratings relative to the group.

Overall, the data returned in the Delphi III revealed relative standings for the eight main biotechnology knowledge areas. These standings were viewed with respect to the degree of agreement reached (Q-values) concerning the level of importance (median scores) bestowed on individual subdivisions within each knowledge area. Ranked by “percent subdivisions rated above the median cut-off point,” the main knowledge areas of *Biochemistry* and *Medicine* proved to be highest. Lowest in the standings, with only 59% of its total subdivisions rated above the cut-off point, was the *Bioprocessing* knowledge area.

The response data gathered from Delphi II, gave early indication of a large degree of consensus by panel members on which subdivisions were considered important for adequate instruction of biotechnology at the secondary school level. Only seventeen out of the total of eighty-four subdivisions were not considered important enough for inclusion within one of the eight main biotechnology knowledge areas. This represented 20% of the total population of subdivisions rated in this study. In the same comparison of Delphi III data, the percent of excluded subdivisions dropped slightly. In Delphi III, only fourteen of the eighty-four subdivisions remained below the acceptable level of importance, representing approximately 17%.

This general shift toward consensus among panel members regarding which subdivisions should be used for the instruction of biotechnology is readily apparent when both Delphi II and Delphi III data are compared. In all eight main biotechnology knowledge areas there was movement toward both a higher rating and greater consensus on the degree of importance for nearly every subdivision. The most marked shift within the eight knowledge areas was found in that of *Biochemistry*, where 76% of its nine subdivisions showed an elevated rating and a higher level of consensus. However, the general trend to shift subdivisions upward in the level of importance was consistent across all main knowledge areas. Table 3 summarizes the data comparisons between Delphi II and III, illustrating the trend to shift subdivisions upward along the scale of importance, and also the general strengthening of consensus revealed in the downward shift of mean Q-values in each main knowledge area. Only those subdivisions at or above the acceptable 8.5 median cut-off point are included.

Table 3
Summary of Trend Toward Higher Acceptable Ratings from Delphi II to III

Knowledge Area and Subdivisions	Rating Level D-II	Rating Level D-III	Mean Q-Value D-II	Mean Q-Value D-III	%Upward Shift
BIOCHEMISTRY			3.2	2.0	76%
Proteins	10.5	11.0			
Social Impact	9.5	11.0			
Control and Regulation	10.0	11.0			
Macromolecular Structure	9.5	10.5			
The Genetic Material	10.0	10.0			
Methods of Analysis	10.0	10.0			
Enzymology	10.0	10.0			
Carbohydrates	9.0	9.0			
Lipids	8.5	9.0			
MEDICINE			1.83	1.33	67%
Social Impact	11.0	11.0			
Molecular Medicine	10.0	11.0			
Immunology	10.0	10.5			
Genetic Therapeutics	10.0	10.0			
Health Care Technologies	9.0	10.0			
AGRICULTURE			2.25	1.75	67%
Tissue Culturing	10.5	11.0			
Plant & Animal Genetic Engineering	10.0	11.0			
Social Impact	10.0	11.0			
Microbial Applications	10.0	10.0			
Plant & Animal Applications	10.0	10.0			
Plant Physiological Systems	9.5	10.0			
Animal Physiological Systems	9.0	10.0			
Agrichemicals	9.0	9.0			
Food Safety	8.5	9.0			
Aquaculture	8.5	9.0			
Food Science	8.0	9.0			
GENETIC ENGINEERING			2.23	1.77	62%
Genetic Code	11.0	11.0			
Social Impact	11.0	11.0			
Analysis of DNA	10.0	11.0			

Table 3 (cont.)
Summary of Trend Toward Higher Acceptable Ratings from Delphi II to III

Knowledge Area and Subdivisions	Rating Level D-II	Rating Level D-III	Mean Q-Value D-II	Mean Q-Value D-III	%Upward Shift
Genetic Engineering Applications	10.0	11.0			
History & Ethics	10.0	11.0			
Basic Structure of Genetic Material	10.0	10.5			
Basic Cell Structures	9.0	10.5			
Vector Systems	10.0	10.0			
Probing Techniques	10.0	10.0			
Molecular Bio Techniques	10.0	10.0			
Basic Research	9.5	10.0			
Genome Projects	9.0	10.0			
BIOETHICS			2.3	1.70	60%
Social Impacts	11.0	11.0			
Principles of Ethics	10.0	11.0			
Impacts of Using Biotechnology	10.0	11.0			
Regulation: Legislation & Safety	10.0	11.0			
Potentials of Gene Therapy	10.0	11.0			
Patenting of Life	9.5	10.0			
Forensics	9.0	9.0			
Technology Transfer	8.5	9.0			
BIOPROCESSING			2.59	1.53	41%
Fermentation	10.5	11.0			
Culturing	10.0	11.0			
Genetic Engineering	10.0	11.0			
Microbial Applications	10.0	10.5			
Social Impact	10.0	10.5			
Separation & Purification Techniques	9.0	10.0			
Bio-Products	9.0	9.0			
Types of Microorganisms	9.0	9.0			
Microbial Structure	9.0	9.0			
Processing Design: Monitoring & Growth	8.5	9.0			

Table 3 (cont.)
Summary of Trend Toward Higher Acceptable Ratings from Delphi II to III

Knowledge Area and Subdivisions	Rating Level D-II	Rating Level D-III	Mean Q-Value D-II	Mean Q-Value D-III	%Upward Shift
FOUNDATIONS IN BIOTECHNOLOGY			3.3	2.1	40%
Laboratory Safety	10.0	11.0			
Social Impact	11.0	11.0			
Scientific Method	10.0	10.0			
Definition of Biotechnology	9.0	9.5			
Historical Background	8.5	9.0			
Relevant Terms	8.5	8.5			
Career Information	8.5	8.5			
Specifications on Lab Journals and Logs	8.0	8.5			
ENVIRONMENT			2.29	1.71	14%
Social Impact	11.0	11.0			
Biotreatment Systems	10.0	10.5			
Biological Controls	10.0	10.0			
Bioremediation	10.0	10.0			
Biorestoration	10.0	10.0			
Safety	10.0	10.0			

Mean Q-values in all eight knowledge areas decreased from Delphi II to Delphi III. This represents a decrease in the interquartile range, indicating a stronger consensus among the panel members for the appropriate level of importance rating given to each subdivision. When the eight knowledge areas are analyzed cumulatively, the move toward consensus is made clearer. The overall mean Q-value for the subdivisions rated in Delphi II was Q(avg.)= 2.45, with a standard deviation of 1.17. In comparison, the overall mean Q-value for the Delphi III data set was Q(avg.)= 1.74, with a standard deviation of .58.

The above calculations, and those given in Table 3, show (a) an overall increase in the level of importance ratings, (b) a marked decrease in average interquartile range, and (c) an overall average decrease in the standard deviation between responses given in Delphi II and Delphi III.

The main biotechnology knowledge areas and their respective subdivisions shown in Table 3 are the final list of knowledge areas and respective subdivisions identified by the panel of biotechnology experts participating in this study as those most appropriate for inclusion in a biotechnology taxonometric structure developed for the secondary school level.

Discussion

The eight main biotechnology knowledge areas identified in this study were found to effectively encompass the subject matter of biotechnology, and constitute the first level in a taxonometric structure for biotechnology at the high school level. The sixty-nine subdivisions with acceptable ratings were distributed among the eight main knowledge areas at varying levels of importance. It was evident from the data that some subdivisions were perceived to be of greater importance than others. The knowledge area with the largest percentage (50%) of subdivisions receiving a rating of 11.0 was *Bioethics*. This suggests that panel members view the subdivisions of this knowledge area as an extremely accurate representation of what should be addressed in *Bioethics*. This indicates that there is a great deal of certainty concerning the importance of these five particular subdivisions by a large majority of the experts. The same can be said for the 19 subdivisions in the seven other main knowledge areas that received ratings of 11.0.

This data implies that a larger number of those subdivisions used in *Bioethics* were perceived to be notably more critical for that knowledge area than were those submitted for the other seven knowledge areas. Along this same line of reasoning, *Bioprocessing* contains the largest percentage of its subdivisions, compared to the seven other main areas, below the median cut-off point of 8.5. The implication here is that a comparatively large portion of those subdivisions submitted for inclusion in *Bioprocessing* were not perceived critical to instruction in this area. In short, a greater majority of subdivisions submitted for the knowledge area of *Bioethics* more closely fit that area of instruction than did those submitted for the other seven. The opposite was found true for the knowledge area of *Bioprocessing*.

The dispersion in subdivision ratings was relatively small in six of the eight main knowledge areas. The percentage of subdivisions rated at the high end of the scale, between r = 10.0 and 11.0, was above 50% for the following main knowledge areas: *(a) Genetic Engineering (92%), (b) Environment (86%), (c) Medicine (83%), (d) Biochemistry (78%), (e) Bioethics (60%), and (f) Agriculture (58%)*. This indicates that the subdivisions in the main knowledge areas are highly accurate in representing the categories of greatest importance when addressing these main areas of biotechnology at the high school level. Moreover, the strength in accuracy is further indicated by how large the percentage of subdivisions are at the high end within a main knowledge area. Specifically, *Genetic Engineering*, with 92% of its subdivisions rated between 10.0 and 11.0, shows it to be the main knowledge area generating the strongest consensus. *Environment* and *Medicine* run close behind, with 86% and 83% of their subdivision, respectively, rated at the high end.

Of the 24 most highly rated subdivisions across the eight knowledge areas, one was common to all. *Social Impact* was rated at 11.0 in all but one knowledge area. It was given a rating of 10.5 in the one outstanding area. The perceived need for instruction on the current and potential impacts biotechnology can have on society was clearly evident among the panel members.

The identified list of knowledge areas and subdivisions serves as a foundation from which to continue developing appropriate biotechnology curriculum for students at the secondary school level. Table 3 presents the final list of knowledge areas, with their corresponding subdivisions rank ordered by Delphi III median scores. The use of this list by educators in technology education or biological sciences is likely to differ according to the approaches to curriculum development and delivery of instructional content within the classroom setting. These alternate uses stem from philosophical differences between science and technology.

Individuals in the field of technology education look to apply knowledge, using technical means, in developing solutions to practical problems. The emphasis is on practice, with processes centered around designing, creating, applying, and ultimately leading to a final outcome that is of practical use. This is in contrast with those in the field of science, biological or otherwise, who strive to understand natural laws and phenomenon through observation and use of the scientific method of investigation. In science the emphasis is on theory, looking to know and understand through observation, discovery, and experimentation in an effort to find a theoretical use for the information gained. The initial biotechnology curriculum taxonomy derived through this research is applicable in both of these approaches. The following example illustrates how this may be accomplished.

In the *Bioprocessing* knowledge area one of the highest rated subdivisions is titled “Fermentation.” It is expected that individuals in technology education would approach this topic in a very applied sense. Fermentation might conceivably be viewed as a componential process utilized in a larger system, only a part of which employs living organisms to produce a product or perform a service. Students would make use of the knowledge that yeast cells oxidize sugar molecules, and in a controlled environment can be made to produce a gasoline substitute such as ethanol. Their efforts might then be directed at the system as a whole, designing it to address a specific need. For example, in the alternative fuels industry efforts continue toward the developent of increasingly efficient means of producing gasoline substitutes. One area within which to increase efficiency is in developing methods for continuous fermentation using an immobilized cell process. The underlying principle is that yeast cells, imbedded within porous beads and submerged in a sugar solution, can still act on the sugar molecules while remaining separate from the solution. This immobilization of the yeast cells provides for quick separation and continuous production of end product, reducing production time and costs.

Understanding the environmental and biological requirements yeast cells have for fermentation to proceed, a method of cell immobilization in gelatinous beads could be designed. In approaching this problem students would need to take into consideration such parameters as 1) selection of the carrier - type of gelatin, 2) design of the reactor and shape of the carrier, 3) selection of the most appropriate yeast strain, 4) prevention of contamination, 5) maintenance of yeast viability, and 6) scaleup methods. This design process incorporates the utilization of a biotechnical process as a component of a larger system.

In contrast with technology education, biological science looks to understand the natural world through investigation into and observation of natural laws and phenomenon. Therefore, in approaching this problem biological science instructors might have students focus more on the mechanisms of oxidation that are involved with the variety of known fermentation processes. Using the scientific method of inquiry students would look to understand how fermentation by certain fungi and bacteria leads to the production of citric and gluconic acids, vitamins such as B_{12}, or some amino acids. The emphasis would be to gain knowledge of the biological methods of fermentation, possibly with the intent of looking for points where the process could be controlled or biologically enhanced.

These examples demonstrate how the same content can be addressed by both the biological science students and technology students, but the context would be markedly different. Based on the taxonometric structure identified in this study, instructional objectives developed for teaching biotechnology courses in technology education and biological science would differ in approach, yet remain centered around a consistent content. As such, they would be ideal for courses run in tandem or parallel. Sequencing of topics to be addressed and coordination of lessons would allow for delivery of fundamental bioscience knowledge in one course, and its biotechnical application in the other.

Biotechnology has come to be viewed as a set of powerful tools based on the knowledge and use of biological systems. Informed use of these tools is imperative, as endeavors in this field will ultimately touch every facet of American life from the water we drink and the food we eat, to the energy driving our machines and the materials used to produce them. The impact, both realized and potential, of biotechnology on our society has spurred efforts to introduce the basic concepts of this field into secondary school instruction. Contemporary technology educators, keenly aware of a natural place within their instructional objectives for the study of biotechnology, are moving to include it within the technology education instructional program. The taxonomy derived through this research would allow for future development of secondary biotechnology curriculum, applicable within either a technology education program or biological sciences program.

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Editorial

Must we MST?

Patrick Foster[1]

Introduction

Among the most highly touted and admirable trends in US public education is subject-matter integration. And among the best and the brightest in the technology education profession are those who are laboring to organize, develop, implement, and assess the integration of mathematics, science, and technology.

But among the most lopsided ideals in our profession is the degree to which the worth of the field is predicated on its image as a full member of a math-science-technology troika.

That's not to say that these researchers and practitioners should abandon this line of integrative research; surely it is worthy of pursuit. But unfortunately, our profession seems to be redefining itself: technology education is incrementally becoming math-science-technology, or "MST." Before we solidify this move, fundamental questions about the relation between technology education and the other school subjects need to be asked.

Addressing Some Questions About MST

Admittedly, asking questions is easier than answering them. However, it is probably much better to question while answers are difficult than to reserve questioning until answers are futile. With this in mind, several points relative to the problem of redefining technology education as MST will be addressed. These relate to the technology education profession's advocacy of MST; the benefits ascribed to MST; the goals of the science-technology-society (STS) movement; the awareness of math and science professionals of technology education; our attraction to MST; and the future of math, science, and technology in MST.

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1. Is MST being strongly advocated by the profession?

As Daugherty and Wicklein (1993) said, technology education has a "stated role of providing interdisciplinary settings for the applications of mathematics and science concepts" (p. 30). They further described "mathematics and science" as "disciplines with which we choose to associate" (p. 30). Technology-education-as-MST seems to be prevalent theme at all levels, from the classroom (e.g. Daiber, 1992) to teacher education (e.g. LaPorte & Sanders, 1993); from state association journals (e.g. Seymour, 1992) to state conferences (e.g. Connecticut Technology Education Association, 1992).

The International Technology Education Association heavily advocates MST ("ITEA in Action," 1993). Two of three refereed articles in a recent issue[2] of *The Technology Teacher* (TTT), its official journal, described math-science-technology projects; the third, written on a technical topic, contained a "math interface" section and a "science interface" section. A recent "Educator to Educator" feature in that journal intended to "answer your questions," posed to prominent educators, about MST. But as opposed to featuring a debate among leaders as to the value of this approach, the respondents were all leaders of existing MST programs; without exception, the questions themselves assumed a great value in MST.

The TTT is not the ITEA's only outlet for MST promotion. Its "very popular" (ITEA, 1993, p. 14) promotional memo pad presents this definition: "Technology Education is: Applying math, science, and technology; solving practical problems…" (p. 14). The association's Council on Technology Teacher Education, in conjunction with NCATE, has put into effect teacher preparation guidelines which "clearly emphasize the importance of the integration of science, technology, and mathematics" (Gloeckner, 1991, p. 80). In other words, technology teacher education programs must demonstrate MST integration in order to be accredited.

Technology-education-as-MST is increasingly becoming popular politically as well as professionally in technology education. In the campaign for 1992-1993 ITEA president, Steven Moorhead ran on a platform encouraging "the active involvement of Technology Education with Math, Science, and other curriculum areas…" ("Candidates for ITEA," 1990, p. 12). Moorhead won the election and delivered on his promise (e.g. "Interdisciplinary approach," 1991, p.10).

2. What are the benefits of MST?

Presenting on the topic of technology teacher education at the Camelback Symposium, Householder (1992) discussed "the preparation of teachers of mathematics, science, and technology in a unified undergraduate program,"

[2] Volume 52, number 6.

adding that this could “enable the profession (technology education) to take advantage of funding opportunities currently available only in science and mathematics” (p. 8). Wescott (1993) noted that “the current emphasis on mathematics and science provides a unique opportunity for technology education to establish itself as a viable discipline to be studied by all students” (p. 177).

LaPorte and Sanders (1993) mentioned several benefits of MST, including elevating technology education to the status of academic subjects in the middle school. Sinn, Walthour and Haren (1993) described “education about technology, science, mathematics and quality” as “part of the historical basis of American greatness in education and industry” (p. 29).

Certainly MST, if nothing else, is an example of an integrative approach — an important methodology in technology education (e.g. Zuga, 1988). But it is a rather lopsided example which ignores the social studies, as well as other, typically cultural, aspects of the curriculum, such as language and art.

“One major difference between traditional industrial arts and contemporary technology education,” said Kemp and Schwaller (1988), “is the inclusion of the *social and cultural* aspects of technology” (p. 21). The contentiousness of this statement aside, every major definition of *technology education* contains a rider clause pledging social concern (e.g. Savage & Sterry, 1990; Israel, Lauda, & Wright, 1993). So where is social studies integration in technology education? And why doesn’t it garner the attention MST does?

3. Isn’t technology education integrating social studies via STS?

Perhaps on face value, the educational movement “Science-Technology-Society” (STS) might appear to integrate the three school subjects in its name. But even the sketchiest overview of contemporary STS literature suggests that this movement is primarily a context for science instruction, and that what we would call “technology education” is not at all considered to be part of STS.

“Science-Technology-Society has been called the current megatrend in *science education*,” Robert Yeager (1993), former National Association for STS president, wrote recently. “Others have called it a paradigm shift for the field of *science education*…the National Science Teachers Association (NSTA) called STS the central goal for *science education* in its official position statement for the 1980s…” (emphases added) (1993, p. 145). In discussing these conceptions of STS, Yeager did not mention technology education or social studies — perhaps because STS is “a new kind of science education” (Solomon, 1993, p. 15) — not a kind of social studies education and not at all a kind of technology education.

Even when invited to write an article in the *Journal of Technology Education,* STS pioneer Rustum Roy (1990) characterized STS as “an approach to ‘science’ education” (p. 14) and “*learning science* through contact with applied science (italics added)” (p. 15).

4. Are math and science leaders conscious of technology education?

While STS leaders rarely seem to recognize the technology education profession when discussing “technology,” the perceptions of other math and science educators revealed in the literature are even less flattering to our field.

In introducing his article *Technology Outlook on Math and Science: Conversations with Experts*, Stinson (1993) wrote that “technology is fueling a revolution in America’s science and math classrooms…Now, teachers can conduct experiments without the need for highly expensive chemicals or in fear of explosions…” (p. 24). Language used regularly in *The Mathematics Teacher*, an official journal of the National Council of Teachers of Mathematics, is similar. The term “technology” frequently means calculators and computers, and almost exclusively describes what we would call “educational technology;” (e.g. Stein, 1993; Day, 1993). Even well-known math and science leaders use the term in this way (e.g. Usiskin, 1993).

An impartial observer might be inclined to conclude that in general, math and science educators are unaware of attempts by technology education to integrate math, science, and technology — and perpaps that they are unaware of technology education itself.

5. So why is MST so attractive to technology education?

It will not come as a surprise to many technology educators that apparently ours is the only educational profession to use the term “technology” to mean anything other than “educational technology.” But when leaders in math and science education use the term in this fashion repeatedly, MST begins to look less and less like a coordinated, three-part alliance and more and more like wishful thinking on the part of technology education. In fact, it goes beyond what Petrina (1993) called “discipline envy —” it’s attempted discipline by association.

Pucel (1992) considered it a “given that technology has content of its own” (p. 8). He hardly seems alone in taking this position. Use of the term “discipline” to refer to industrial education was common during the early 1980s (e.g. Balisteri, 1982; Hales & Snyder; 1982, Lauda, 1982), and is now more common than ever. Many in our profession have for some time advocated the “disciplining” of technology and technology education. Clearly math and science are disciplines. Perhaps we find MST attractive insofar as it allows us to associate with what we aspire to be.

Moreover, some public-school industrial arts teachers feel that “technology” has been handed down to them without an instruction booklet, except for ivory-tower curriculum documentation. So far this has succeeded in further clouding the issue of what public school teachers are supposed to teach (e.g. Hutton, 1992; Nee, 1993). MST may do the opposite by narrowing the scope of technology education to the point where it may be manageable to teach. Certainly the prospect of determining our content base is attractive to our profession.

6. Will public school math/science integration ever happen?

In its recent standards document, the National Council of Teachers of Mathematics emphasized mathematics as communications, reasoning, and problem-solving. Increased material manipulation is being emphasized in school mathematics (NCTM, 1989). The American Association for the Advancement of Science's landmark Project 2061 (in which several technology educators were involved as reviewers) contains "benchmarks for science literacy." In addition to those which relate to general science, physics, and biology, they include "The Mathematical World," "The Nature of Mathematics," "The Nature of Technology," and "The Designed World" (AAAS, 1993). Clearly, the distance between school mathematics and science is small and getting smaller. Our fantasy role as the interface between math and science may become unnecessary before it can become reality.

Furthermore, the AAAS and NCTM documents are K-12 curriculum statements. Among technology educators, references to "K-6 technological awareness" may suffice, but even if we were offered a full partnership with math and science, how could we possibly excuse or explain our apparent lack of concern for students until they're half-way through school?[3]

7. Is the curriculum of MST really big enough for all of us?

In less than a decade, the School Science and Mathematics Association will be celebrating its 100th anniversary; to be sure, "science and mathematics have allies in their role as a necessary component of public educational institutions, where IA/TE has not been championed to the same extent" (Volk, 1993, p. 54). If math and science really have these bases covered, what benefit could math and science leaders see in including what they still percieve as industrial arts?

Meanwhile, our own confusion is abetted by the common lack of distinction, for example, between mathematics as a pure science and the study of

[3] Although it is beyond the scope of this article, it could be demonstrated that the original intent for "industrial arts" was exclusively as an elementary-school study. Its originators at Teachers College, Columbia University, expected the manual, domestic, and home-economics subjects to take on a vocational nature in secondary education. But to a degree the opposite of this has happened. High School industrial arts (technology education) has commonly been taught as a general education subject separate from vocational education, while the elementary grades have been largely ignored.

mathematics.[4] Both the NCTM's *Standards for School Mathematics* (1989) and the AAAS's *Benchmarks for Science Literacy* (1993) unequivocally consider mathematics to be a "science," which, in differentiating that term from "technology," Dyrenfurth (1990) defined as the "explanation of nature" (p. 13). But when Dugger (1994) described mathematics as "dependent upon technology" (p. 8), one might assume he was suggesting that the *study* of mathematics depends upon technology (i.e. computers, compasses, calculators, etc.) — not that technology, which is human in nature, can have any impact on the laws of mathematics.

Clearly, the laws of science and mathematics can and have existed without technology. They do not need technology; they do not depend upon technology. Furthermore, human beings do not need technology to study them.

However, it must be conceded that nearly all studies of science and mathematics have been made possible by the *products* of technology — from the pen and paper a zoologist uses to record the movements of animals in nature to the compass and straightedge a mathematician uses to perform a geometric construction (n.b. Maley, 1985). If the field of technology education really believes that natural scientists (including mathematicians), are concerned with "detached" and pure, as opposed to applied, knowledge (Wright, 1992, p. 16), then scientists and mathematicians must be seen as the consumers of the products of technology — not consumers of the knowledge of technology.

But technology need not be defined solely with respect to the natural sciences. It need not be relegated to the objective, analytical, "detached" studies. And it need not be regarded as a discipline of the order of mathematics and science. Technology can be viewed broadly as a "total social phenomenon" (Pfaffenberger, 1988 p. 236) — not simply as a would-be partner to mathematics and science.

This directs attention back to the question: why are we defining technology education as MST? Lewis (1994) recently implored our field to "abandon attempts to acquire social status, and, instead, to be true to itself — to become authentic" (p. 23). Perhaps we should consider that in its original general-education conception, technology education (industrial arts) was to be entirely integrated — integrated with the whole curriculum, not just one or two subjects. "It is not a special subject in the sense of being unrelated to other subjects, but, quite the contrary, it is rather the most general subject of all in its far-reaching relationships" (Bonser & Mossman, 1923, p. 74). For technology education, acheiving a balanced integration would be acheiving authenticity.

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[4]A discussion of the failure to distinguish between natural science and its study would take the same course. Mathematics is used here as an example.

The Final Question: So What?

Perhaps it is true that technology education is attempting to gain credibility by associating with reputable school subjects. Perhaps it is true that teachers of those school subjects feel they are already teaching technology. Perhaps it is true that MST is an example of successful integration which ignores some school subjects.

So what?

Unfortunately, what makes technology-education-as-MST so easy for us to swallow is that it is that part of industrial education which math and science teachers are expected to teach. If we strongly identify ourselves as MST, and if math and science teachers begin to really teach what they claim as their subject areas, technology education could quickly become an unnecessary duplication of services.

The ideals behind MST are noble: to capitalize on the similarities between school subjects, and to draw often distant areas of the public school curriculum together. But for the technology education profession to do this to the exclusion of subjects much more closely related is at best a misrepresentation of the nature of technology; and to do so in an attempt to establish our body of knowledge as a discipline hopefully isn't a last-ditch grasping at respectability.

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