

Design: The Only Methodology of Technology?

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The Nature of Technology

Technology, and certainly technology education, can be characterized as more of an activity than a discrete body of content (McCormick, 1996). Technological knowledge can be divided into procedural knowledge which relates to the activity, and conceptual knowledge which relates to the body of content (Hennessey & McCormick, 1994). There is probably more international agreement among technology educators about the activity of technology than about the content of technology. This is a helpful separation to make when designing curriculum and discussing teaching, but it is not a separation which should be evident to the students. Students should perceive technology as a thoroughly integrated activity, not one which can be separated into content and process, or theory and practice. Some curriculum documents separate these two areas of knowledge. An example is the two attainment targets in the UK technology curriculum of Design and Make. In others, the differentiation is less such as the Content Standards of the Technology for all Americans Project (ITEA, 1998).

While the traditional focus of technology education has been on activity, i.e., on doing and making things, this has represented a narrow interpretation of procedural knowledge. This focus has not been accompanied by an emphasis on all aspects of procedural knowledge, but has typically been concerned with those procedures most closely aligned with the development of manipulative skills and how to use tools effectively and safely, for example.

A relatively recent realization has been that there are many significant cognitive skills which are important for students to develop, and which are suitable to be developed in the unique context of technology education. The term unique is appropriate because there is no other curriculum area in which students have as significant an opportunity to think and reflect and develop ideas, and then to test their ideas in a practical context. The development of these cognitive skills occurs through the procedural knowledge of technology education.

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Procedural Knowledge

Procedural knowledge is developed through the creation of a process, as when a solution to a particular need or brief is sought. There are a range of these processes which are utilized in the development of technology and therefore may also be appropriate in teaching technology, the two most common being design and problem solving.

The place of procedural knowledge in the US Standards for Technology Education is developed as "Design," proposed as one of the five major organizers of technology education. This equation of the technological process with design is further reinforced by another of the organizers, namely "The Designed World."

A common approach in teaching the technology process is to map out a series of steps for students to follow as they make projects. Examples include design-make-appraise (Australian Education Commission, 1994), identify-design-make-evaluate (UK Department of Education, 1995), and define problem-ideas-model-test (USA International Technology Education Association, 1998). The idea is that this systematic process can be taught and learned by all pupils who can then apply it to subsequent problems or situations. These are often reproduced in booklet form as workbooks for students to use as they design. However, research has revealed that it does not work this way, either in reality or in the classroom. Neither students nor designers naturally utilize a predetermined process in their work; they invent a process as they proceed toward task completion. This is well illustrated by Petroski (1996) in his book *Invention by Design* where he details the design and development of things like paper clips, pencil points, and zippers.

The parallels with science education are interesting. As with technology, and even more specifically with design in technology, studies of scientists at work seem to indicate that there is no generalizable method (Carey, 1994; Gibbs & Lawson, 1992; Chalmers, 1990; Gjertsen 1989). The notion that there is a common series of steps followed by all research scientists, such as defining the problem, gathering information, forming a hypothesis, making observations, testing hypotheses, and drawing conclusions, is not generally held.

One of the reasons for the continued perpetration of this myth is the way in which results are presented in research journals (Medawar, 1990; McComas, 1996). The standardized style of presentation makes it appear that all scientists follow a standard research plan. Scientists approach and solve problems in many different ways, using the skills and methods used by all problem solvers in whatever area.

The Processes of Science and Technology Education

Both the content and the processes of school science have traditionally been drawn from the pure science category of scientific activity. This means that the content was studied in strictly disciplinary categories, and the process was a prescriptive and linear one of defining the problem, gathering information, forming a hypothesis, making observations, testing hypotheses, and drawing conclusions. This method serves to work against the creativity element in

science. For example many laboratory exercises are simply verification activities where teacher discussion is followed by step-by-step instructions and work toward a predetermined solution. This is the antithesis of the way science really operates, and is no longer generally accepted as appropriate (Woolnough, 1994).

An advantage of science over technology in the educational context is the definition of the body of knowledge within which the processes can be pursued. Despite the fact that many science educators are calling for a reorganization of this content into something which is more relevant and meaningful for students, the traditional organization is accepted and in place. Fensham (1985, p. 417) makes a similar point with regard to science, that despite the rapid growth of scientific knowledge, the specific conceptual content in science education consolidated rather than diversified, the rationale being that the "powerful" organizers were those which scientists everywhere used repeatedly. In technology there is no comparative consensus on the conceptual organizers of the content, although attempts have been made to this end in the USA (Hales & Snyder, 1982; ITEA, 1998).

An analysis of the way scientists work, and the development from that of skills which may be appropriate in the teaching of science, has been done in many curriculum projects (Woolnough, 1994). In commenting on this reductionist approach, Woolnough concluded that it is not very helpful because doing science is more than being competent in a series of scientific skills. "The whole activity of doing science does not equal the sum of the parts, it differs from and exceeds it" (p. 18). This method of deriving processes from the real world, however, is not necessarily reductionist, and could remain a valid insight for students into the world of doing science.

In technology, what Woolnough refers to as the reductionist approach is a recognized source of ideas about processes. The methods used in the advance and development of technology are recognized as appropriate methods and processes for technology education. But at the same time there is recognition that technology is also more than the accomplishment of a set of process steps. The outcome of a design, or the solution to a problem, involves more variables than can be represented in a sequence of process steps.

This reductionist approach to processes in science or technology serves to identify many of the individual and specific activities in which practitioners engage as general life skills, such as planning, observing, reporting, evaluating, and communicating. These activities only become science or technology when they are contextualized, when they are accompanied by scientific or technological knowledge, and set in the context of a scientific investigation or a technological design.

Constructivism

The current incorporation in science education of constructivist notions of learning are not derived from the conduct of real science, but rather from research about the way students learn. Constructivism holds that students learn by constructing knowledge in certain ways, and the teaching of science will be facilitated if the presentation of content is organized in these constructive ways. Real science is not really done constructively, nor is scientific knowledge

developed constructively. The goal of scientists is often not necessarily to simply add to the domain of scientific knowledge (even in pure science this may be a spin off rather than the primary goal) but to understand, for example, how a specific object functions or behaves. There is a difference between scientists' cognition and students' cognition; children construct knowledge in different ways.

Is constructivism then also an appropriate approach to technology education? I don't think so, because the development of knowledge is not the primary goal in technology. Knowledge is only developed to the extent that it assists in the completion of a task; the criterion becomes: *Is it useful?* Not, as in science, where the criterion is: *Is this knowledge appropriate in the development of students' perceptions of the theory of the reality around them to explain their sense impressions?*

So while in science education the presentation of new knowledge to students must be carefully selected and managed to allow its construction in relationship to what is already known, the rationale for the introduction of new knowledge in technology is its usefulness in progressing toward the completion of a task.

General Versus Vocational Approaches

Questions related to the importance of the process must also relate to the vocational or general philosophy of the subject. Where the goal is vocational, in science to prepare scientists and related professionals, and in technology to prepare technologists at all levels from engineers to tradesmen, then the assumption is reasonable that the methodologies employed in teaching, and the consequent processes employed by the students in learning, should be derived from the practice of the discipline. If however the goal is general, to develop a more scientifically or technologically literate citizenry, then what is the rationale for deriving the educational processes from the discipline? Surely it would be more reasonable to derive them from learning theory, and to some extent this is happening in science education.

For technology education, however, this logic does not apply because the procedural knowledge enhances the level of general technological literacy in the area. For example, if in technology a design process was being utilized as both the pedagogy of the moment and the process that students follow in a particular task, then conforming to a constructivist framework for the development of knowledge would be inappropriate. This is due to the fact that a structured sequence in the development of knowledge/understanding is irrelevant given that the defining criteria for relevant knowledge is not what fits together developmentally, but that which works toward the satisfaction of the design brief.

The compatibility of vocational and general approaches to either science or technology has been rejected (Fensham, 1985, p. 417; Williams, 1998) despite, or in spite of, continued curriculum development efforts to amalgamate the two. The approaches are incompatible in terms of methodology (teacher centered vs.

student centered), assessment (competency vs. outcomes), and pedagogy (didactic vs. inquiry).

Technology Processes

There is a range of activities in which students are engaged when they “do” technology. They do not necessarily do all the activities every time they complete a task, and certainly do not do them in the same order every time. The activities depend on the nature of the student and the nature of the problem. There are many activities in this process, but the most important include:

- evaluation,
- communication,
- modeling,
- generating ideas,
- research and investigation,
- producing
- documenting.

It may be appropriate that these activities be called *aspects* rather than *stages* of the process; *stages* has a sequential connotation which is not appropriate as a technology process.

If these aspects are standardized and sequenced for all students for all projects, then it is not possible to achieve the goal of revealing the cognitive development of students through the documentation of their design process. This is the case because they are being forced into a way of thinking that has been predetermined by the teacher. Their cognitive development is neither revealed nor encouraged. These activities are not ends in themselves, but rather are done and practiced in order to achieve other goals. These other goals include students becoming independent problem solvers, becoming creative and reflective, and becoming critical and expressive; that is, the goals are achievement of the generic competencies that all students need and should have upon leaving school (Mayer, 1992).

The situation in Western Australia is representative of more global thinking about the nature of the processes of technology. There has been a move away from the notion of a prescribed process such as Design-Make-Appraise (Australian Education Council, 1994) to the idea that there is a range of processes in which students are engaged when they do technology (Curriculum Council, 1997). These processes of technology may include those enumerated in the following section.

1. Design

Design is justifiably the most common and popular of the processes appropriate to technology education, and has been identified as such in the US Standards for Technology Education (ITEA, 1998). In the real world it is a significant process in the development of technology in many disciplines from engineering to architecture, and from an educational perspective it is an ideal methodology to use as a vehicle to achieve the desired competencies.

There is very little research about design, and therefore very little informed guidance on how to teach it. But there is some. There seems to be no simple

generalizable process. "The processes involved in designing are not linear, they do not always start from human needs, and they do not always proceed in an orderly way. They are reiterative, spiraling back on themselves, proceeding by incremental change and occasional flashes of insight" (Baynes, 1992).

Research has been conducted on both expert designers and children doing design in a technology education context with some parallels in the findings. What students do when they design in technology is a very convoluted and complex process, and is different every time they design something. Studies of designers working in technological fields also reject the notion that what they do can be represented by an algorithm (Hennessey & McCormick, 1994). So both seem to adopt inventive and flexible approaches which are adapted to the situation in which they are working. Individuals also seem to have preferences for how they design.

In the design situation where teachers insist on progressing through set stages, students in fact adopt their own strategies in order to get the job done, but ritualistically use the teacher's approach to satisfy assessment demands (Hennessey & McCormick, 1994). For example in the common requirement to sketch four design alternatives to a problem or brief, a student is often interested in only one, and does the others just to satisfy the teacher. In this case the goal of generating creative ideas is not being achieved and students do not reflect on the process, for example, by asking what, why, what order? This requirement therefore has no impact on student thinking or the development of creativity.

2. Problem Solving

The appeal of problem solving as a methodology lies in the fact that it is a natural activity; humans have always been faced with problems and tried to solve them. In this sense it is also a useful model for understanding technological development in that it can incorporate the broad range of variables involved in the solution to a technological problem.

Despite the fact that the terms *design* and *problem solving* are often used interchangeably, problem solving is different from design in that design deals with ill defined problems and may not begin with a problem, while of course problem solving does.

It is helpful to clarify different types of problem solving. McCormick (1996) identified three types of problem solving:

- a general problem solving approach referring to the process more than the problem itself.
- a global problem referring to a significant problem, the solution to which will take some time.
- emergent problems which arise throughout any process and must be overcome in order to proceed.

3. Systems Approach

A systems approach (input-process-output) is often placed in a problem solving context. For example, in many technology curricula in the USA a system is represented as a solution to a problem. A systems approach may be either

analytical, and thereby used as a way of viewing the world or a specific context or object, or functional in that a systems process is followed for diagnostic or production purposes.

Many generic groups of systems are represented in the literature. Examples include structural, mechanical, electronic, communication, production, transportation and biotechnological systems. These systems represent much of technology, and are often used to reduce a technology to a simple graphic model that illustrates basic elements. This representation can extend to quite complex elements such as systems maps, influence diagrams, and flow-block diagrams (McCormick, Newey, & Sparkes, 1992, p. 146)

4. Invention

Inventions may be accidental or intentional. Authors such as Ferre (1995) equate the accidental with the notion of practical intelligence in technology, the “trial and error” and “all or nothing” approaches. The intentional is conversely associated with theoretical intelligence, where each element contributing toward a technological solution can be isolated and analyzed for its effectiveness. A method can be articulated, aligned with the notion of theoretical intelligence in technology, which represents a systematic and deliberate process for the pursuit of new inventions (Ferre, 1995, 40). For example:

- Mental envisionment: What do I want?
- Articulation of theoretical consequences: What would happen if...?
- Construction of an artifact: Will this do it?
- Empirical observation of the outcome: Did it work?
- Comparison: What went wrong?
- Re-articulation of theory: Perhaps this would work?
- Isolation of elements: Was this the problem?
- Modification of the artifact: Now lets see...
- Fresh empirical observation: That works better.

To the extent that this is a realistic process, invention can be encouraged in the classroom. A deeper discussion of the psychology of invention would be necessary to ascertain if the characteristic of invention itself can be taught. But generally speaking, a classroom climate, and an understanding of what constitutes a technology process can both be conducive to the acceptance of invention when it occurs in a classroom.

5. Manufacturing

A manufacturing orientation to technology covers a number of more specific types of processes such as a custom made craft approach, a production line, batch production, and one-off production. In each of these processes, factors to consider include materials, capital, information, transportation, time, and energy. This is an accepted feature of many technology education programs, and continues to be justified because it is an important aspect of real-world technology.

There are many other processes that are used in various technological contexts and could be used by teachers to help represent the breadth of

technology to students. For example, repair and restoration, or the development of a business plan, could each be a valid process.

The Teaching of Processes

The variety in pedagogy afforded by the utilization of a range of processes has a number of potential advantages:

- appeals to the preferred learning styles of a range of learners
- makes both teaching and learning more interesting
- more adequately reflects technology

The difficulty in teaching these processes of technology becomes apparent when students are not all doing the same activity at the same time. This means that the students in a class cannot be treated the same as far as teacher attention is concerned. Despite the fact that all students may be working on the same problem, they may be utilizing different processes in seeking a solution, and aiming toward different solutions. Thus, the demands for guidance from the teacher vary. The following are some anecdotal ideas to deal with this situation.

1. Begin with a large group.

In this approach, a situation, problem, or brief is presented and discussed with a class. Then, consensus agreement is reached on a procedural sequence through discussion by class members. After agreement about the approach has been achieved, the teacher can then put a label on each of the activities. For example, “when we looked at similar products on the market, we were evaluating,” or “when you asked your friends and neighbors how much they would pay for the product, we were doing market research.” The determination of the process is not then dependent on an individual and students begin with the necessity of the activity rather than the possibly meaningless label that goes with it.

2. Don't expect too much too soon from students.

Because the skills involved in technology processes are complex and convoluted, and are different each time a solution to a problem is attempted, it will take a long time to teach the various aspects of processes. It will require even more time for students to practice using those processes selectively and effectively. Lower secondary students should not be expected to proceed individually through a sound and comprehensive self directed technology process. It is not until the upper secondary level that this should be expected to take place.

3. New conceptual and procedural knowledge.

New knowledge must be taught on a need-to-know basis. It is not good enough to tell the students that “teacher knows best, and while the material currently seems irrelevant, there will come a time when it is needed.” Because the processes are complex, they should be taught bits at a time. The skill (and most difficult part) of teaching technology is to manipulate students to the point where they realize they need the information you want them to have. The

situation should not arise where technology students are stuck in a classroom for the first few weeks of a course because of all the information they need to have in order, for example for them to be able to do design. This will destroy their motivation and enthusiasm for the subject. If students are given information when they realize they need it, their level of retention is higher and they will learn more efficiently.

4. Large projects which last for an extended period of time.

When the students are involved in large projects which last for a period of time, introduce smaller support tasks to give practice in specific skills which can then be immediately applied to the context of the task in which they are working. For example shorter tasks could include the development of a particular graphics skill, practice in identifying peoples' needs, or the identification or manipulation of systems.

5. Minimize the separation of theory and practice.

The continual interaction between the thinking skills and the concrete reality of activity is what enables the development of capability in technology (Kimbell, 1996). But often and in many ways we indicate to students that these two areas are discrete. This separation is evident in:

- timetabling - theory and practical sessions scheduled at different times
- examinations - separate theory and practical exams
- the use and design of work spaces - theory areas and practical areas
- teaching methods - lecturing versus demonstrations.

Students should get the clear message, both through overt and covert strategies, that theory and thinking in technology cannot be separated from technological activity. Either without the other is not representing technology adequately to students.

6. The process can begin at different places.

The point at which the process begins will depend on the outcomes the teacher wishes the students to achieve. It may begin with:

- exposure to a situation, from which students extract a problem,
- a description of the problem,
- a brief already written by the teacher,
- an individual and predefined interest or need,
- an existing product, which is then evaluated for redesign.

7. Support the required skills.

Students must be taught, and then given the opportunities to practice specific skills and techniques before expecting them to incorporate them into a process of technology. Most technology teachers do this well in the area of manipulative skills, but it is also essential for the cognitive skills. For example if we want students to generate ideas, then we need to teach them the skills of brainstorming and morphological analyses. In researching they must be taught survey design or how to use indexes. Specific sketching skills must be taught for

them to be able to record ideas. If metacognition is expected, then they need to understand how they think.

8. The sequence of the process.

The point at which the process is initiated may dictate the beginning of the sequence of activities. For example, if a product is to be examined for redesign, then evaluation occurs first; if the activity results from personal need, then the generation of creative ideas may not be necessary. It may be appropriate to prototype ideas early in the process, then go back and revise the brief. As previously stated, there is no set process.

9. The end result of the process may vary.

The most common end result of a design process is a product, but it could just as appropriately be a model or prototype, environment, graphic, system, or service. If a course of study in technology always results in one type of output, there is a danger that the student will develop a limited perception of the nature of technology.

Conclusion

There are many reasons why it is important for students to utilize a range of processes when developing their technological literacy and capability. Technology is such a broad area that a focus on any one process will not provide students with a broad concept of the nature of technology. All students have preferred learning styles, and utilizing a range of processes in teaching technology will appeal to more students than would the use of a single process. It will also make the teaching of technology more interesting to both students and teachers.

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