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ABSTRACT

Technological efficacy is the knowledge, ability, and desire to create, select, apply, monitor, evaluate, communicate, and otherwise bring to fruition desired technology in a given context. This document is a qualitative synthesis of research related to technological efficacy, including exploration of its definition, psychometric properties of instruments, and studies of structures and correlates. Didactic, descriptive, and causal-comparative research efforts are summarized. Variables correlated to technological efficacy include: (1) affective factors; (2) gender; (3) age; (4) teaching method and curricula, and (5) other exposure to technology, like media consumption, work experience, hobbies, family environment, and college major. Recommendations for future research involve studying all demographic groups, employing case studies, building empirical models and standardized instruments, and investigating technological efficacy curriculum. (Contains 15 references.) (BEW)

Running head: STRUCTURE AND CORRELATES OF TECHNOLOGICAL EFFICACY

The Structure and Correlates of Technological Efficacy

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Abstract

Technological efficacy (TE) is the knowledge, ability, and desire to create, select, apply, monitor, evaluate, communicate, and otherwise bring to fruition desired technology in a given context. This document is a qualitative synthesis of research related to TE. Didactic, descriptive, and causal-comparative research efforts are summarized. Studies that have developed TE instruments and investigated their psychometric characteristics are also reviewed. The structure and correlates of TE are discussed. Variables correlated to TE include (a) affective factors; (b) gender; (c) age; (d) teaching method and curricula; and (e) other exposure to technology such as media consumption, work experience, hobbies, family environment, and college major. Recommendations concerning future research are included.

Abstract

this document is a qualitative

The Structure and Correlates of Technological Efficacy

The term *technological literacy* (TL) has steadily risen in the lexicon of buzz words. Many profess that TL is vitally important to us and that we are all in need of more of it. Several states mandate that TL be part of their school curricula. Several professional organizations aim to promote TL. One organization, the International Technology Education Association (ITEA), claims TL as its major focus and accordingly has as its major goal the enhancement of students' TL. Business leaders and politicians are also interested in TL. In 1987, then Governor Clinton said about the future:

> Even those citizens who have no interest in being technical workers
> will have to understand the complex technical and scientific issues
> to make public policy and judge its effects. (Clinton, 1987, p. 16)

A technologically literate populace (a) can make wise decisions about technology; (b) adapt to work, home, and societal technological changes; and (c) cooperatively participate to creatively solve technological problems on the job and as citizenry.

A body of knowledge exists that defines TL in terms of learner outcomes (Hayden, 1989), however, there are many unanswered questions: (a) are all people, the typical person, or various subgroups prepared to understand, apply and/or make decisions about technology; (b) what is the TL level of United States citizens and various subgroups; (c) can and should this level be increased? A nationwide description and norming of TL levels are necessary for developing and seeing to fruition national efforts to enhance literacy concerning technology and its concomitant benefits. However, no nationwide, normed TL instrument exists.

Though used frequently in scholarly writings, the term technological literacy (TL) has not been adequately researched to provide a comprehensive understanding of its meaning and dimensions. The following illustrates this point. Technological literacy has been an *ERIC* descriptor since 1982. A recent *ERIC* search by this writer revealed the following. More than 680 *ERIC* citations use *technological literacy* as a descriptor. Additional documents contain the term within the abstract. When truncated, synonymous, and related terms are included in the search, e.g., *techni**, *litera**, *operacy*, *attitude*, and *efficacy*, more than 35,000 documents are selected. Other databases, e.g., *Dissertations Abstracts International*, contain additional documents that mention TL.

Examination of documents using TL as a descriptor leads to the finding that the majority are didactic in nature; few are research-based. Of the research-based documents, approximately 10 are quantitative in nature; only a few of those are causal-comparative. This document is a synthesis of research related to TL. The specific intent is to explicate the current collective understanding of TL. There have not been enough TL studies to warrant a meta-analysis based on effect size. Therefore, this document is a qualitative synthesis of extant research.

Examination of writings reveals that when most writers use the phrase *technological literacy* they are referring to a much broader meaning than traditional concepts of literacy, e.g., reading, writing, communicating, and understanding. Technological literacy, as it is most often described, includes the constructs of emotion, proactiveness, empowerment, skill in using and creating, and others. Due to the inclusion of affective and psychomotor constructs in the defining of TL, this writer proposes that the totality of our interaction with technology would best be labeled *technological efficacy* (TE). Technological efficacy could be conceptualized as a union of the interdependent domains of knowledge/literacy, affective/affectacy, and psychomotor/operacy. In scholarly articles, concepts that could be labeled *technological affectacy* (TA) and *technological operacy* (TO) are often discussed as subsets or synonyms of TL. However, they are equivalent subdomains covered by the umbrella domain of TE. For the remainder of this document, unless a subdomain is being specified, the term TE will be used as the general term to encompass TL, TA, and TO.

Terminology

It is prudent at this point to define major terms as they are operationalized in the literature and this manuscript.

System — a set of things that have relations to each other and the whole and that collectively behaves differently than when separated. Interconnectedness is a key concept to systems. To act *systematically* is to have a procedure to follow. The act *systemically* is to behave codependently — in a way not divisible into discreet constituents. Culture and its subsystems, technology and its subsystems, and TE and its components all behave systemically.

Technology — the system of processes by which humans adapt to and transform their environment. Technology includes technique. However, more than method, technology incorporates the study, theory, and principles of a process. Key points are that technology (a) is an evolutionary universal human activity; (b) includes inputs/resources, process, output, and feedback; (c) is much more than tools, technique, or the application of science; and (d) via interconnection with the ideological and societal systems defines any given culture.

Technological — pertaining to technology. Etymologically, technological is that which pertains to the process of experiencing or doing (*al*) and is characteristic of (*ic*) the expression or science of (*logy*) skill (the Greek *techne*).

Technique — also, technic — skill in performance. Technique is concerned with effective systematic behavior in contrast to systemic relationships.

Technical — pertaining to technique. That which is technical, is characteristic solely of the application of skill and lacks the broader scientific and systemic nature of an *ology*.

Efficacy — the condition of being able to produce a desired outcome. Efficacy assumes effectiveness and efficiency of action.

Literacy — the condition of being able to communicate, comprehend, and act upon information. Traditionally, literacy focused on the act of reading and writing. Increasingly, literacy has come to include interpreting and communicating via symbols, maps, tables, figures, charts, and other graphics. Literacy has also expanded from comprehension to higher levels of cognitive activity. Literacy is primarily concerned with the cognitive domain.

Affectacy — the condition of having feeling or emotion. Literacy and operacy are abilities; affectacy is a state. Attitudes, opinions, and inclinations belong to the affective domain and are externalized in our behavior.

Operacy — the condition of being able to physically perform. Operacy carries with it the concepts of empowerment, safe and fruitful completion, and efficiency in action. Operacy is an expression of the psychomotor domain.

Technological efficacy — the attributes (intellectual, emotional, and physical) necessary to cause a desired technological outcome. Alternatively, the knowledge, ability, and desire to create, select, apply, monitor, evaluate, communicate, and otherwise bring to fruition desired technology in a given context. Table 1 summarizes TE and its components.

Technological literacy — the knowledge to create, select, apply, monitor, evaluate, communicate, and otherwise produce a desired technological outcome.

Technological operacy — the skills and abilities to create and apply technology in a safe, effective, and efficient manner.

Technological affectacy — the attitudes, beliefs, emotions, and other mental states related to technology.

Table 1

Summary of Technological Efficacy and its Sub-Domains

Term	Domain	Attributes/Descriptors
Technological Efficacy	Umbrella domain encompassing all personal factors necessary to produce a desired technological outcome	appropriateness desired outcome effectiveness efficiency systemic utility/usefulness
Technological Literacy	Cognitive	analysis communication comprehension deduction evaluation knowledge thought understanding
Technological Affectacy	Affective	beliefs emotion feelings lack of anxiety proactivity states values
Technological Operacy	Psychomotor	accomplishing application creating doing manipulating safety skill technique

Note: All the domains are mutually supportive and interrelate. However, most research has focused on an isolated domain.

Synthesis of Research

Empirical research is scant involving TE and its subdomains. Most scholarship has centered on philosophically defining and conceptualizing TL. Most publications have been qualitative or subjective in nature. Technological efficacy research can be stratified in various ways, e.g., domains of knowledge, demographic and/or independent variables studied, or technological subsystem.

Research regarding TE has included (a) definition, (b) development and description of the psychometric properties of instruments, (c) structure investigation, and (d) correlate investigation. Most research has been exploratory and preliminary in nature, having been conducted with delimited demographic groups, e.g., high school students in Iowa, and/or concerned with a narrow stratum of technology, e.g., manufacturing technology. Most research has dealt with middle school-, high school-, and college-aged students.

While there are many possible conceptual subsystems of technology, e.g., biomedical, agricultural, ad infinitum, the ones most often investigated within the framework of TE have been communications/computer technology and industrial technology. This is understandable given that most early TE theoreticians were members of the ITEA (formally the American Industrial Arts Association) or the National Association of Industrial Technology.

Both TL and TA have received a similar and small amount of attention. There has been no research targeted at actual TO, although there is much extant research on specific skills and physical activities. The research involving TO has been self-reported or opinionnaire in nature, and therefore more directly related to TA.

Research in TE can be summarized as in table 2. Focus refers to domain of investigation, i.e., TL, TA, or TO. Coverage refers to the generalizability of the research due to the sample characteristics.

Table 2

Summary of Technological Efficacy Research

Category of Research	Subcategory / Purpose With Representative Researchers	Domains of Technological Efficacy — Literacy	Affectacy	Operacy
		Synthesized Focus and Coverage		
Didactic/ Philosophical	Theorized description of, content of, and need for TE. Dyrenfurth & Kozak; Hayden; Hirsch, Kett & Trefil; Johnson; Pytlik, Lauda & Johnson	P C	S C	S C
Descriptive	Delphi-type determination of TE content. Baker; Barnette; Croft	P C	M C	M C
	Self-reported TE (TA only). Bame, Dugger, de Vries & McBee	M D	P D	M D
	Self-reported TE (TL & TA). Hayden; Welty	P D	S D	S D
	Measurement of TE. Bame, Dugger, de Vries &McBee; Hameed; Hatch; Hayden; Kuforiji	P D	P D	E D

Instrumentation	Item/Instrument Development. Bame, Dugger, de Vries & McBee; Hameed; Hatch; Hayden; Kuforiji	P E	P E	S E
	Psychometric Analyses. Hatch; Hayden	P C	S C	M E
Causal-Comparative	Predicting TE. Hayden	P D	M E	M E
	Investigating correlates of TE. Hayden	P D	S D	S D
	Comparing means of TE measurements. Hayden	P D	S E	S E
	Investigating structure of TE. Hayden	S D	M E	M E

Key:

M = minimal coverage	S = secondary focus	P = primary focus
E = exploratory/pilot study	D = delimited inquiry	C = comprehensive inquiry

Examination of the previous table reveals that there has been no widely generalizable research concerning TE or any of its subdomains. Furthermore, TO has received scant attention. Most research concerning TE has been of a preliminary type on a small scale. The most thorough analyses have been of TE instruments. However, none of these instruments have undergone comprehensive field testing or have been applied to the collection of nationwide normative data.

Theory and Didactic Scholarship

The content base for technology extends to all areas of human activity (Pytlik, Lauda & Johnson, 1978). The case can be made that most human ideas, activities, and creations are linked to technology. The epistemology of technology begins with the earliest of ancient philosophers; continues through the likes of Rousseau, Pestalozzi, Whitehead, and Dewey; and continues expanded today (Gilberti, 1989). The American Association for the Advancement of Science recognizes technology as a discipline related to but separate from science (Johnson, 1989). In accordance with technology's unique discipline base, education about technology has its own professional organization — the ITEA. Technology education is a recognized accreditable subject area. Every state has technology education courses at one or more levels in the kindergarten through twelfth grade range. These are most often titled *Technology Education* but also carry other labels. Technology teacher education programs are approved by the National Council for Accreditation of Teacher Education, following guidelines established by the ITEA and its affiliates. The ITEA defines technology education as

> A comprehensive, action-based educational program concerned with technical means, their evolution, utilization, and significance; with industry, its organization, personnel, systems, techniques, resources, and products; and their social/cultural impact. (International Technology Education Association, no date)

Technology and TE have been exhaustively defined (Baker, 1989; Hayden, 1989). Nearly all writings concerning TE have been of the opinion type; most describe technology, state what should be known about it or what we should be able to do with it, or discuss how to teach it. Since 1952, the Council of Technology Teacher Education has published an annual volume devoted to education in technology; Volume 40 focuses specifically on TL/TE (Dyrenfurth & Kozak, 1991).

Most writings focusing on TE or one of its subdomains make the case for its importance and claim the populace does not possess enough TE. Maley (1985) notes that, "in 1984 alone, ten major studies of education were reported...each one calling for changes in school to prepare our students to live in a technological society" (p. 16). Since 1984, these kinds of calls for increased TE have grown at an exponential rate. Many professionals in education and other fields are concerned about the level of TL displayed by the American public. They voice an opinion similar to Connie Ley (1987), namely, "the level of technological literacy to which educators and others are able to bring the general population will determine the future world in which humankind will exist" (p. 7).

Much theorizing has taken place concerning the structure, teaching, and learning of technology and TE (Gilberti, 1989). The thought given to TE has focused on the TL component; the operacy and affectacy components have received scant theoretical attention. In brief, the major points of TE theory can be summarized as follows.

1. Technology is a major system of human adaptation. The technological system contains factors unique unto itself but also shares variance with the other major human adaptive systems, i.e., the ideological, and sociological systems. Any defined culture is so defined by the communality of its ideological, sociological, and technological systems.

2. Technology is a learned phenomenon. Therefore, being efficacious with technology is largely a learned phenomenon.

3. Technological literacy is more closely related to achievement than aptitude.

4. Technological efficacy is worthy of being partitioned from the broader realm of general achievement and ability. The trait should discriminate on correlates divergent from those that predict general achievement and ability.

5. A person's level of TE should increase with age due to developmental factors.

6. A person's level of TE increases with additional learning and exposure related to the attribute.

7. Being a learned attribute, it is tenable that TE is influenced by the individual's learning style, prior learning, aptitude, interests, opinions/perceptions, the learning environment, and other factors related to learning.

To date, research has supported and refined the theory above. However, there is still much to be discovered about the structure of TE, how we acquire it, and how we utilize it.

Instrumentation

Few instruments to measure TL have been developed. Few of those have focused on TE as it is broadly defined. Several audiences would like to utilize tests of TE; there are none commercially available. To this author's knowledge, no instruments to specifically measure TO have been developed. Numerous instruments have been developed to measure manipulative skill, dexterity, and similar attributes that probably share variance with TO. Self-reported TO has been measured. This writer categorizes self-reported TO as TA because an opinion of self is being measured in lieu of performance. It is interesting that the only domain that can be realistically (philosophically speaking) quantified is the psychomotor. However, efforts thus far have focused on measuring and evaluating the affective and cognitive — attitude and thought.

Instruments to measure TL and TA have been developed by a variety of methods. Most have been developed without a procedure to ensure that the domain was measured inclusively and proportionately. Some TE tests have had their content validity described by the opinion of portended experts (Hameed, 1988; Kuforiji, 1992). Other instruments have been developed by a systematic procedure to select or create items, hopefully, building in content validity (Hatch, 1986; Hayden 1991 & 1994). Both, Smalley (1981) and Gilberti (1983) developed early TL tests. These were not based on a test plan, nor was psychometric data collected. Hatch formed a post hoc TL subtest from the Science section of existing National Assessment of Educational Progress questions and data. Both Hameed and Hayden (1991) developed tests of industrial technological literacy. Hameed's was narrowly focused on specific technical knowledge; Hayden's on generalizable technological knowledge. Kuforiji designed a TL test largely based on content in the *Encyclopedia Britannica*. Kuforiji did not report the rubric used to create times. Kuforiji did state that the items were intended to measure the knowledge level of Bloom's taxonomy.

Recently, Hayden (1994) developed and applied several additional instruments to measure components of TE. These instruments include the following:

1. A test (divided into four subtests) of TL based on the *Technology* Chapter from Hirsch, Kett and Trefil's *The Dictionary of Cultural Literacy*. Cultural literacy is conceptualized to be a body of knowledge shared by literate Americans. Hirsch's et al. work garners input from several hundred people. The intent was to include topics between the generalized and the specific. For example, names of common tools, e.g., a hammer, would not be included. Conversely, highly technical concepts considered above cultural literacy would also be omitted. Items were only included if the content was considered to have lasting influence and not be of a temporary nature (Hirsch, Kett & Trefil, 1988). Hirsch's et al. work draws from many national periodicals. In Hirsch's et. al. words,

> We reasoned that if a major daily newspaper refers to an event, person, or thing without defining it, we can assume that the majority of the readers of that periodical will know what that item is. (Hirsch, Kett & Trefil, 1988, p ix)

2. A test of TL based on the *New York Times* Index. Articles in the *New York Times* are abstracted in a searchable index. Similar to Hirsch's et al. reasoning above, Hayden reasoned that technology terms used in the *New York Times* would be expected to be understood by the readers of that periodical, i.e., the public.

3. Three similar instruments intended to measure opinion of TL level. The instruments list attributes of the technologically literate person as determined by Delphi-type techniques (Barnette, 1990; Croft, 1990). One instrument measures self-reported TL, another asks the respondent to assess others' TL, the third seeks the respondent's opinion about how much TL the average person should have.

4. Sub-tests to assess individual's opinion and knowledge of (a) the definition of technology, (b) the characteristics of technology, (c) the control of technology, and (d) the acquisition of TL.

5. An instrument to measure the individual's perceived pervasiveness of technology.

6. An instrument to measure the individual's attitude toward the extent that various entities, e.g., the self, employers, schools, should be involved in teaching or learning TL.

7. A demographic instrument to collect data empirically or philosophically related to TL.

Hameed, Hatch, Hayden (1991 & 1994), and Kuforiji's studies collected psychometric data and established tentative norms for TE. These instruments supplied evidence that TE is a valid measurable construct. Additionally, Hayden's studies have investigated the correlates, prediction, and structure of TL.

The psychometric characteristics of most instruments have been satisfactory. Item and instrument characteristics have typically exhibited values similar to published norm-referenced instruments. Internal consistency reliability is normally .8 or higher, and up to .98 when corrected for attenuation of quantity of items. Within instruments, item means of objective items when corrected for guessing are approximately .5, and item intercorrelations average up to .45. Instruments to measure TL exhibit strong positive intercorrelations. Intercorrelations among TL score and scores of traditional general achievement areas, e.g., math or language, are similar to the intercorrelations among those traditional areas. Tests of TL have psychometric characteristics similar to extant achievement tests but account for unique variance in achievement. These findings and others lead to the conclusions that TE (or at least TL) (a) can be measured with reliability, validity, and utility; (b) is worthy of being partitioned from general achievement; and (c) is not synonymous with or exclusive to science or other subsets of general achievement.

Causal-Comparative Research

While relatively restricted in quantity and scope, the results of quantitative research concerning TE illuminate several interesting findings. The most notable of these are the factors related to TL level and attitude toward technology.

Correlates. Certain variables are related to TE. Many of these variables are demographic in nature. These variables include: (a) affective factors, (b) gender, (c) age, (d) teaching method and curricula, and (e) other exposure to technology. Exposure to technology could include media consumption habits, work experience, hobbies, family environment, college major, and others.

Exposure to technology has usually been found to correlate positively with TE. However, not all exposure is equal. Hayden (1994) concluded that some types of increased exposure to technology leads to a false confidence in self-perception of personal TL level. Interpersonal and ipsative differences in attitude also affect TE.

Hayden (1994) found the following concerning TL level.

1. Individuals with differing technical backgrounds view technology and TL in significantly different ways. Technically-specific individuals have a narrow view of technology and the entities responsible for instilling TL.

2. The more an individual is exposed to technology, the higher they tend to self-assess their TL level.

3. The more an individual is exposed to technology, the higher they tend to believe others' TL should be.

4. Exposure to technology is not related to the respondent's opinion of the average person's TL level.

Most studies find differences in TE related to age. This is not surprising as age is related to development. What may be surprising is that very young children can relate to and interact purposefully with technology. Krendl, Clark, Dawson and Troiano (1993) found that most three year old children have access to a VCR and can manipulate the machine to meet their specific viewing desires. Thirunarayanan (1990) found that subjects could relate to technological issues that have personal implications, e.g., transportation safety, by the fifth grade. By ninth grade, subjects could relate to personal, interpersonal, societal, and environmental technological issues. Hayden (1989) found that grade level accounted for unique variance in TL scores. There is a developmental progression to the understanding of technological issues and the attainment of technological knowledge.

The technological literacy of the aged is of interest to several audiences. It is often erroneously assumed that older people do not use technology, do not know much about technology, and/or are intimidated by technology (Czafa & Barr, 1989). There is no evidence that would lead to this conclusion. James (1993) found that older people are less informed about computers and more informed about health, transportation, banking, and household technology (ipsative comparison). However, more than 50% of those seniors surveyed were interested in learning more about computers. Because of changing age demographics, employers are likely to make greater use of older workers.

Almost every TE study that collected gender data found differences between the sexes. For example, (a) being male usually accounts for approximately twice the variance in TE score as female, (b) males score higher on TE instruments, and (c) instruments and items display preferable psychometric characteristics when measuring males. The last finding may be due to instrument bias and/or the low variability of females' scores due to females scoring lower and fewer females having been tested.

Researchers such as Thirunarayanan have found gender differences in the way females view technology. Girls tend to view the application of technologies in terms of their social consequences. Boys tend to view machines and technology more positively — as doing people's work for them. Girls as young as 5th grade tend to view machines and technology more negatively — as replacing people. Thirunarayanan found that automation was a concern for females and concludes that female attitudes may be why few females are in technical careers.

Gender differences in attitude toward technology may be due to differences in how boys and girls are socialized. Krendl et al. found gender differences in VCR use related to differences in family socialization patterns. Females consider more entities descriptive of technology than do males (Hayden, 1994). Females also, rate more entities as having a desired responsibility to instill TL (Hayden 1994). The conclusion is that females are more sensitive toward technology, while males are more mechanistic.

As previously mentioned, parental socialization of children impacts the child's attitude toward technology. Hayden (1991) has found that parental contact with technology is related to TE scores. Krendl et al. found that the characteristics and capabilities of the technology have little to do with its integration into the home/family. However, access to and instruction on the technology does contribute to its integration into the home/family.

Hayden (1994) found a strong positive correlation between the amount of technical/technology magazines read and level of TL. Technological information is often mathematical in nature. Deluca (1991) found that organization into a mathematical format increases understanding of technical text. Males may be more inclined toward technical content and/or mathematical representation. Causation concerning these relationships has not been investigated.

Similar to technical print, viewing television programs of a technical nature correlates positively with TL (Hayden, 1994). Interestingly, viewing television programs of a nontechnical nature correlates negatively with TL

Most students are exposed to technology as part of their school curriculum. The teaching methodology and content espoused by the ITEA positively correlates with TE (Hayden, 1991 & 1994). Studying a specific type of technology probably leads to increased technical literacy. It is tenable that intense exposure to specific technology would tend to focus the individual on definitions and entities applicable to that specific technology. But this technically literate person is not necessarily one that is technologically literate (Shearrow, 1992). Hayden (1991 & 1994) has also found the following.

1. Courses with a craft or hobby emphasis do not add to TL.
2. Courses that focus solely on skill development do not add to TL.

3. Students with nontechnical majors rate more entities as having a desired responsibility to instill TL.

4. College students enrolled in technical majors tend to rate industrially related terms more descriptive of technology than do nontechnical majors.

5. College students enrolled in technical majors and males are more likely to rate industrial and governmental related entities as having a high desired involvement with TL.

Prediction. In Hayden's 1994 study, up to 70% of TL and TA score could be predicted using demographic data. It was found that individuals with differing technical backgrounds view technology in significantly different ways. Individuals with low TE scores have had relatively little exposure to technology, are unsure of technology, and do not have strong opinions concerning who should be responsible for technology. Interestingly, having the opinion that employers have the main responsibility for ensuring that individuals are technologically literate is negatively correlated with TL score. The ratio of technical television to nontechnical television watched is the best predictor of TE (Hayden, 1994).

Structure. The construct validity of TL has been established by Hayden (1991) and others (Bame, Dugger, de Vries & McBee; Hameed; Hatch; Kuforiji). Theory states that the TL part of TE is a subset of general achievement. The TA and TO portions of TE have not been investigated as well. It has been shown that TL is not just science or math or a combination of those (Hayden, 1991). Correcting for attenuation in reliability, the shared variance between TE score and other subtests of general achievement have range from 36% to 56% (Hayden, 1991). These percentages are large enough to imply a meaningful relationship between the latent trait being measured by TL score and that being measured by other general achievement subtests. However, the shared variance is not so large as to negate TL instruments as supplementary means of measuring general achievement.

Factor and qualitative analyses of TE instruments have extracted factors that could best be labeled as cognitive, affective, and psychomotor (Hayden 1991 & 1994). However, further investigation into the structure of TE is warranted. It has been substantiated that TE exists and can be described and measured.

Description of Technological Efficacy Level

Every researcher that has investigated TE has exhorted the opinion that the TE levels of the population being studied were not high enough. However, there has never been a nationwide norming of all demographic groups. Scores on objective TL instruments tend to be approximately 50% when corrected for guessing. This is ideal for psychometric purposes. However, there is no basis, other than personal opinion, that any given score is a good or bad score. TE levels have been linked to knowledge, attitudes, and behavior that have been subjectively judged as to their value.

Hayden (1994) found that subjects had no understanding of their own TL level but felt that they and others were in greater need of TL. Welty (1992) conducted a study in which the subjects were generally satisfied with their level of awareness and their access to sources of information concerning technological issues. However, Welty found that a small percentage (approximately 10%) of the public is attentive to technological issues and engages in political decision-making or debate regarding those issues. Welty concludes that the public does not have enough access to or knowledge of sources of information concerning technological issues.

Compared to how a TE investigator would describe technology, subjects have a narrow view of technology, how it is acquired, and who should control it. Welty found that the public is willing to let technological experts make technological decisions even when those decisions affect the individual and are within the sphere of influence of the individual. Hayden (1994) found that most subjects select business/industry and the government as knowledgeable about technology and being the entities that should instill and control technology. Hayden (1994) found that individuals who obtain higher TL scores believe that citizens should control technology and that schools should teach about technology.

Summary

Results indicate that technological literacy exists and can be measured with a high degree of reliability and utility. There is an expanding theory of and theoretical base for TE. Technology, therefore TE, is not synonymous with or exclusive to science. Efficacy with technology can be increased by methodology and content congruent with that espoused by the ITEA. Technological efficacy can be predicted by data that are easily obtained. Populations sampled have generally had no understanding of their own TE level but felt that they and others were in greater need of TE components. Individuals with differing technical backgrounds view technology in significantly different ways.

Discussion

Fundamental questions need to be answered. How efficacious with technology are we? How efficacious with technology do we need to be? Can individuals increase their TE; if so, how can TE be increased? Who should be responsible for instilling and/or increasing TE?

The super technologically efficacious have been labeled *technocrats*. However, there is no evidence of the existence of technocrats. Those with much specialized technical knowledge and specific exposure to individual technologies (the technically literate as opposed to the technologically literate) do not score significantly higher on TL instruments than do those with general knowledge. It appears from the data that individuals with focused technical backgrounds narrowly define technology, restricting technology to their field of view. These focused individuals tend to be older and male They voice the opinion that business and industry should control technology and the dispensing of technological knowledge. Table 3 summarizes the heretofore discussed technology types.

Table 3

Technology Types

Comparison of Technology Types	
Technologically Efficacious	Scores high on TE instruments. Self-perception of possessing adequate TE. Exposure to a variety of nonspecific technology. Believes others need to have more TE. Believes the general populace should be in charge of technology. Believes general education has the primary duty to instill TE.
Technically Efficacious	Scores average on TE instruments. Self-perception of possessing adequate TE. Great exposure to specific technology. Does not believe others need to have more TE. Believes business and industry should have the greatest control over technology. Believes specialized programs should be responsible for instilling TE. Tend to be older, male, and have more work experience.
Technologically Non-Efficacious	Scores low on TE instruments. Self-perception of not possessing adequate TE. Little exposure to technology. Does not believe others or themselves need to have more TE. Does not voice a clear opinion of who should be in charge of technology but believes that citizens are not the best choice. Does not voice a clear opinion of which entity should have the primary responsibility of instilling TE.
Technocrat	No proof of existence. Hypothesized in the literature to possess great technical and technological efficacy and to be in control of technology.

Recommendations

Research concerning TE is still in its infancy. Scant work has been done concerning TO. The majority of research has centered on TL. However, this research has generally been limited to college and high school students. Also, the industrial stratum of TL has been investigated more so than others. The most generalizable work has involved TA. However, most of this has been conducted with middle to high school-aged pupils. The following are recommended as next steps in the overall TE research effort.

1. Research involving all demographic groups.

2. Research by other appropriate methods, such as, historical and case-study.

3. Empirical model building to describe the components of TE and their relationships among themselves and with other factors.

4. Development of standardized instruments, widely normed and bias free, for use in research and to describe, predict, diagnose, and certify TE and its subdomains.

5. Determination of normative levels for TE?

6. Further causal-comparative investigation into TE and its subdomains, especially TO, and correlates.

7. Inquiry into the amount and nature of TE needed?

8. Investigation into the optimum TE curriculum and methodology. Primary questions would include (a) what causes and hinders TE; (b) how can we increase TE; (c) what is the best curricula content for TE; and (d) what are the best learning environments, teaching methods, and instructional materials?

Summary

What we know about technology, what we can do with it, and how we feel about it are likely to remain topical questions. Technology is growing exponentially and our interactions with it are becoming increasingly complicated. Questions about our efficacy with technology are increasing faster than they can be answered. Researchers from numerous disciplines can and should engage in basic and applied research concerning our efficacy with technology.

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