# Tolerance of Ambiguity in Educational Technology:

# A Review of Two Social Science Concepts

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**ABSTRACT**

How does a concept acquire its meaning? How does a learner acquire a concept? Answers are explored through historical review of two social science concepts: tolerance of ambiguity (TA) and educational technology (ET). Each of these concepts accommodates multiple interpretations. Limitations in dominant interpretations of each concept are exposed using three analytic perspectives: theoretical, ecological, and phenomenological. The first concept, TA, originally conceived as a personality trait, acquires additional meaning when re-interpreted as a metacognitive skill. As such, TA refers to an ability to cope with increasing sensitization to novel features of a phenomenon in order to redefine prior conceptual interpretations, contingent on trust and motivation. The second concept, ET, concerns the application of technology for purposes of learning. ET is popularly conflated to mean the application of computer technology; however, less intuitively, technology refers to myriad ideas and processes, including cultural, biological, and metacognitive processes. As a metacognitive strategy for conceptual change, TA can be exploited in ET theory and practice. In particular, securely experiencing the ambiguity that is inherent in a phenomenon (for example, the ambiguity inherent in a concept such as TA or ET) equips learners to overcome the restraints of prior knowledge, toward the cultivation of new knowledge.

*Keywords:* concept formation, educational technology, metacognition, phenomenology, tolerance of ambiguity

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*Dedicated to Gary Boyd*

*who relentlessly surprised, inspired, and pushed me*

## List of Figures

## List of Tables

## Introduction

The conceptualization of any phenomenon can be investigated with respect both to ontology and to epistemology (Slaney & Racine, 2011). Scientists, invested in refining and discovering ontological concepts, ask questions related to reality: what does a concept mean, what is its nature? Meanwhile, educators, interested in the knowledge of such concepts, may ask questions related to epistemology: how does one *acquire* these concepts? Finally, critical theorists may ask a third question, recursively casting epistemological light onto matters of ontology: how does a concept acquire meaning or nature in the first place?

In comparison to pure sciences, in which matter is more readily measured, social sciences are particularly plagued with problems related to objectification. Social science constructs[1] readily admit multiple interpretations. For example, concepts such as "intelligence" and "technology" are ambiguous. What do these concepts mean? If scientist-practitioners cannot agree on ontological definitions, how do they acquire and work with these concepts?

In the present research, I investigate two social science concepts that lack consensual definition. Specifically, I investigate the ambiguity inherent in the following two concepts: "tolerance of ambiguity" (TA) and "educational technology" (ET). Each of these concepts is subject to multiple interpretations. The goal of this research is to clarify how critically tolerating multiple interpretations of these concepts can contribute to their valid and productive use.

[1] I use the term "construct" to refer to a formal/theoretical research concept. I use the term "concept" to refer more loosely to a general idea. The evolution of research constructs may undermine their formal/theoretical conception. So, generally, I prefer to use the term "concept" throughout this paper, in order to expose the epistemological challenges that are inherent in these social science constructs.

I have divided this research into five sections. First, I provide a statement of my research problem and method as well as a brief review of the overall results of this research. Second, I provide an overview of theoretical assumptions that inform this work. Third, I review the TA concept, including its history, theorizations, and construct limitations. I propose an interpretation of TA that acknowledges its mutability as a personality trait and its operationalization as a metacognitive skill. Fourth, I review the ET concept. I begin this section with broad theoretical conceptions of education and of technology. Then I review the history of ET, describing limitations in its theorization, and I propose an interpretation of ET that accommodates soft technology. Finally, I conclude by proposing theoretical relevance of TA to ET.

***Problem Statement***

Each of these concepts, TA and ET, lacks clear definition. They admit multiple interpretations. They continue to evolve. Some constructions of TA and ET lack validity due to their limited conception. Interpretations that dominate the literature obscure the potential strength of each concept.

The first concept, TA, is itself related to problems of ambiguity. Specifically, TA concerns one’s ability to perceive and to manage multiple interpretations of the same phenomenon. I first encountered the TA construct while investigating individual differences in response to ambiguous visual stimuli. However, incongruous definitions in the literature cast doubt on my comprehension of the construct. TA appears to me as a skill – a proficient way of thinking that could be learned – yet many academics refer to it as a stable trait. The second concept, ET, concerns the application of technology for purposes of learning. Technology is a broad term, which includes ideas, processes and ways of thinking. However, technology is often conflated to mean computer technology; and ET is often misunderstood to mean only the application of computer technology, which severely limits the construct's potency. Uncertainty concerning how these concepts can and should be construed led me to the present research. I interrogate these concepts individually, toward qualitative theoretical understanding of each. I also explore their reciprocal merit, as each concept can be interpreted as the application of strategic thinking toward the cultivation of knowledge. The present research questions are: What is tolerance of ambiguity? What is educational technology? How might tolerance of ambiguity and educational technology be relevant to one another?

***Method***

My research method is historical and descriptive. I collected data about each concept in turn by reviewing related literature. In addition, my inquiry has a theoretical design. By finding and evaluating contradictions and limitations in past and existing theories of each construct, I iteratively return to the literature for further analysis and synthesis, ultimately to advocate for particular theoretical models that overcome apparent limitations. To aid my analysis, I employ two broad theoretical assumptions. Specifically, I assume that all knowledge is grounded in experience, which problematizes unequivocal certainty. Furthermore, I assume that both personality development and technology development are evolutionary processes, the theorizations of which demand critical reflection. I attempt to engage the complexity of my two central concepts, TA and ET, by examining them at multiple levels: theoretical, ecological, and phenomenological. At a theoretical level, constructs are operationalized for consensual use (e.g., within a scientific paradigm). At an ecological level, the meaning of a concept is contextualized in relation to situational and cultural affordances. At this level, because situational and proximal qualities play potentially pivotal roles in their interpretation, concepts cease to appear universal. At a phenomenological (subjective) level, concepts are contemplated from the perspectives of individuals who experience them practically. I describe these assumptions further in the section entitled Theoretical Assumptions, below.

***Results***

TA theoretically refers to an individual's ability to accommodate multiple interpretations and to self-regulate through the cognitive dissonance that may result. TA is commonly theorized as a personality trait. This conception suggests that TA remains stable over time (similar to other personality characteristics, such as eye colour). Beyond a trait, some researchers (especially educators) interpret TA also as a skill, part of a larger metacognitive process. In this theorization, TA refers to an ability to increase sensitivity to novel features of a phenomenon despite conflicts with prior knowledge, provided that sufficient trust and motivation exists in order to engage the process. At an ecological level, environments are understood to demand and to afford different levels of TA. Subjectively, TA can be understood as it is exercised by individuals to re-interpret phenomena that might otherwise appear fixed and stable. As an example, in the present research, the concept of TA itself ceases to appear fixed and stable: while historical and contemporary literature predominantly construes TA as a trait, the concept can be extended and interpreted also as a skill. In light of this reinterpretation, TA resembles a style of thinking. In other words, TA can be interpreted as a technology: a strategy for the perception of and production of meaning. TA can be useful, for example: in tasks that require critical analysis, to unsettle dominant discourses, to further scientific inquiry, and toward conceptual change and growth.

ET theoretically refers to the selective application of resources for purposes of learning. “Resources” can be interpreted to include styles of thinking. However, ET is commonly theorized in limited reference to hard technology (i.e., computer hardware or software); for example, political discourse related to ET reveals strong bias toward applications of computer technology. Many researchers rebuff this interpretation. For example, the Association for Educational Communications and Technology (AECT) emphasizes the inclusion of “intellectual” processes in their definition of ET. However, the AECT interpretation is also limited: it prioritizes rationality over technology, which deemphasizes technological intentionality and the cultivation of rationality itself. Limited interpretations of ET can be remedied in part through the application of TA: sensitization to novel aspects of ET can be achieved by analyzing ET at various levels. At a theoretical level, scientist-practitioners acknowledge the organic nature of technology and its role in the cultivation of knowledge, which includes the development of future technologies. At a cultural level, technology must be understood as a ubiquitous and dynamic field into which humans are embedded. This implies that technology is not merely an intellectual process; technology is also a cultural force that affords and constrains intellect. Subjectively, we may recognize (and responsibly use) our technological saturation: biology and mind extend into and through material and conceptual culture. As we shape technology, so it shapes us.

In conclusion, I suggest that TA, when understood as a style of thinking, can be exploited within ET. TA can be interpreted as an educational resource that can be applied selectively for purposes of learning. As a technology, TA reveals potential to be fostered and modelled. For example, educators can facilitate TA's demands for sensitivity to novel aspects of phenomena and educators can foster the trust that is required to hurdle beyond current limits in knowledge. Exercising TA can elicit productive growth in theoretical understandings. This paper represents an application of TA: for me, TA enabled richer conceptions both of TA and of ET. I end this paper with examples and suggestions for further research. I hope these insights might prove useful to educational technology students, practitioners, and researchers, particularly those who emphasize "soft technology", that is, who investigate, design, or utilize technology related to "styles of thinking". I suspect TA is especially useful in contexts that demand critical evaluation of dominating discourses and methods.

## Theoretical Assumptions

I have conducted my theoretical analysis through a framework of assumptions. This section reveals some of those assumptions. First, I assume that knowledge cannot be disconnected from human experience. This implies that knowledge is not a transcription of reality. Knowledge is an interpretation, sometimes biased, which suggests that alternative interpretations are possible, sometimes preferable. Second, I assume that science is not value-neutral. Different values produce different results. This fact serves to explain some of the divergence in current research related to TA and ET. Third, I assume that human development, including cognitive development, occurs within complex systems. Anticipated and unanticipated changes emerge dynamically over time. Internal and external causes feed into one another; no absolute separation can be drawn between mind, body, and culture. I disagree with assumptions that skills (and acquisition of skills) rest squarely on innate dispositions. Finally, I recognize the field of personality research as pre-paradigmatic. Further description of factors that affect personality may improve research convergence. Specifically, the field demands theoretical, ecological, and subjective perspectives. All of my assumptions are based on the work of various philosophers and researchers, which I describe, below.

***Knowledge is Grounded in Experience***

The “problem of induction” refers to David Hume’s centuries-old riddle, which appears at once to support and to refute scepticism (Millican, 2011). The problem with induction is that there is no way to justify this logic, logically. The only justification for an inductive statement (that generalizes from the past in order to predict the future) is by appeal to past experience, which is tautological. A critical implication of Hume’s riddle is: “causes and effects are discoverable not by reason but by experience” (Locke, Berkeley, Hume, 1990, p. 324).

Hume’s conclusion challenges the possibility of certainty in knowledge. However, according to Millican (2011), Hume’s scepticism is ambiguous. That is, Millican interprets Hume’s conclusion about induction in two ways. With regard to the *logic* of induction, Hume is sceptical. Yet with regard to the *function* of induction, Hume remains non-sceptical: induction remains our only recourse: experience is the only path to conceptual understanding. Hume thus naturalizes certainty by acknowledging theoretical limits. We can enjoy modest certainty in specific knowledge until experience provides reason for doubt. In this light, Hume is recognized as a critic of dogmatic doctrines and an advocate of modern science.

In place of a “spectator theory of knowledge” (that is “the separation of knowledge from practical activity”), John Dewey suggests that knowledge reflects warranted consequences of deliberate actions (1929, p. 126). Warrant, of course, is ground in social and historical context. Like Hume, Dewey destabilizes certainty and advocates for inquiry. In Dewey’s terms, the security that we seek in certainty must be transformed “from inert dependence upon the past to intentional construction of a future” (1929, p. 290). In other words, we find freedom and security not in antecedent certainty, but by engaging in, and learning to trust, active inquiry.

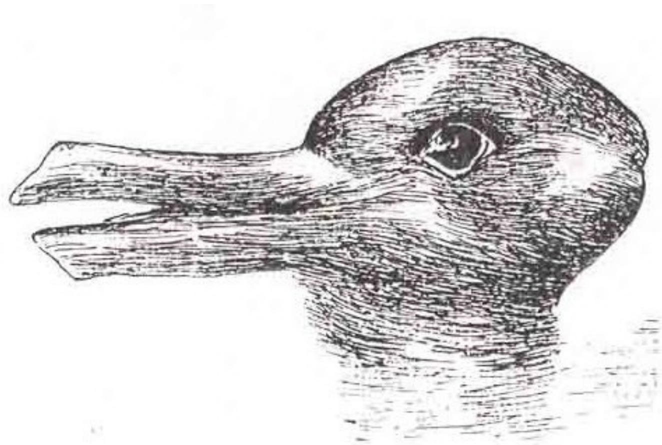

*Figure 1.* Duck-rabbit illusion: subject to interpretation

Similarly, Ludwig Wittgenstein rejects a “picture theory of language”, whereby words are understood as categorical (reified) labels that correspond to essential representations (e.g., Biletzki & Matar, 2011). Instead he advocates for a theory of “family resemblance”, whereby words are understood through meaningful relations to reality. While the picture theory usually works, Wittgenstein warns that its reifications are illusory: rigid categorical labels ultimately elicit inadequate pictures of reality, which naturally leads to philosophical confusion. As an example, he refers us to the duck-rabbit illusion (see Figure 1). What is it in reality? When you see it as a duck, it ceases to be a rabbit: it deserves the label duck. When you see it as a rabbit, it no longer appears as a duck. From another perspective, it is an illusion: it deserves both labels. Or, you may see it merely as ink on paper (or contrasting pixels on a computer screen): it deserves neither label. In any case, the label does not correspond to an "absolute" reality; rather, the label corresponds to use: you use the label to report your relationship to the image.

Representational theories of mind are challenged further by Jerome Bruner, who wrote that a learner is not "a passive recording receptacle" (Bruner & Goodman, 1947, p. 33). Two mid-twentieth century experiments illustrate how expectations and values influence individuals' interactions with the real world. When shown a series of playing cards from a trick deck, participants neglect to see inappropriately coloured suits; for example, red spades are unexpected so misidentified as hearts (Bruner & Postman, 1949). Fortunately, after participants are explicitly informed of the incongruous suits, then they are no longer tricked; they are able to respond accurately. In a different experiment, Bruner and Goodman (1947) suggested that poor children overestimate the size of coins more than rich children do: "the reasonable assumption is made that poor children have a greater subjective need for money than rich ones" (p. 39). In other words, poor children appear to interpret the "idea" of money differently than do rich children. These experiments illustrate how situations, expectations, and values impose on interpretations of the world.

Amos Tversky and Daniel Kahneman have revealed numerous cognitive biases that preclude perfectly rational evaluations (see Kahneman, 2011, for a retrospective treatment). These biases include: confirmation bias (overconfidence in evidence that favours prior conclusions), representativeness bias (overemphasis on similar characteristics and insensitivity to statistical odds), and availability bias (overreliance on readily available exemplars and correlations). Subject matter experts are not immune to the effects of these biases. Professionals in diverse fields including medicine, law, and science routinely exhibit overconfidence, hypothetically due to: the influence of preferences on beliefs (e.g., the Pollyanna principle), the inertia of framing and anchoring (snowball effect of attention leading to more attention), and educational effects (we are trained to justify our ideas, as opposed to contradict them, which predisposes us to confirmation bias) (Nickerson, 1998). In general, illusions of validity reveal limits of rationality: we often prefer rules of thumb over formal logic; we identify readily accessible ideas more easily than remote truths. The popularity of picture theories of language and spectator theories of knowledge can be understood in part through cognitive biases. As we practice these biases, often with good results, these biases naturally self-perpetuate. Dominant discourses benefit from positive feedback loops. In the present research, readily accessible and dominant interpretations of TA and ET often eclipse inherent complexities.

### *Values Inform Science*

Many philosophers acknowledge that science involves social and historical construction (see, for example, the work of Thomas Kuhn, Bruno Latour, and Ian Hacking). This implies that science is not an institute of final, authoritative truth. While the methods of science (observation, replication, falsifiable hypotheses) are designed to allow us collectively to analyze reality as closely and honestly as possible, because these are human activities, we must acknowledge that these activities are bound by human values and expectations, which include culturally constructed beliefs about science and technology.

The molecular status of a single helium atom provides a compelling example of a concept's ambiguity across contemporary scientific paradigms (Kuhn, 1970, p. 50). Different interpretations arise from different emphases in evaluation. According to a chemist, an atom of helium is a molecule because it behaves according to the kinetic theory of gases. According to a physicist, an atom of helium is *not* a molecule because it displays no molecular spectrum. Each scientist views the particle "through their own research training and practice" (p. 50). This example demonstrates ambiguity in the pure sciences. We naturally expect considerably more inherent ambiguity in the social sciences.

To understand how values influence conceptions within natural and social sciences, we must apply the critical reflection that science demands, recursively, upon the methods and history of science. "Critical transparency" – the careful analysis of science and technology – is the term David Waddington (2010) uses to combine Dewey's lofty optimism for individuals in society to comprehend science and technology with Latour's deconstruction of the social constitution of science and technology. Critics of Dewey point out that modern science and technology is too complex and inaccessible. Latour, meanwhile, argues that all scientific facts and technologies are human inventions that become subsumed under an aura of authoritative truth, which undermines their interrogation and understanding. Critical transparency represents a step toward ameliorating the inaccessibility of science and demystifying the technology. Specifically, to entertain Dewey's vision, "teachers need to pursue two closely linked goals: (1)

encourage students to inquire about the history and everyday practice of science and technology; and (2) persuade students to question the dominant discourses of science and technology" (Waddington, 2010, p. 631).

Abrami et al. (2008) concur that critical thinking must be made explicit as an educational goal. The challenge to educators, however, is that critical thinking "is a complex and controversial notion that is difficult to define and, consequently, to study. Furthermore, the tools of implementation (instructional interventions) are difficult to operationalize" (p. 1003). In the present research, I suggest that TA represents an operational adjunct to critical thinking and to critical transparency. For productive regulation against dominant discourse, one must first entertain alternate interpretations of that discourse. This is precisely the capacity afforded by an ability to tolerate ambiguity: sensitivity and trust to entertain alternate interpretations. Research related to development of TA raises potential for educators to nurture this skill.

***Learning Occurs within Complex Systems***

A systems approach to learning acknowledges complex feedback between internal and external causes. Internalized values affect behaviour; simultaneously, our bodies and external environments also act upon us. Expected and unexpected changes emerge over time, from systemic interactions. Some examples of ecological effects on cognitive development include: Lev Vygotsky's famous hypothesis that inner speech (thought) emerges from outer speech (language) and that outer speech emerges from interactive exchanges with culture and caregivers. In this view, thinking begins in a shared space "outside" of the body before its apparent incorporation. In corroboration, Deb Roy's (2005) Artificial Intelligence models support the idea that both humans and robots acquire language by filtering words through environmental affordances. This perspective overcomes problems with purely symbolic explanations of language acquisition (whereby words represent things or categories)[2] by focusing on contextual dependence, as understood through experience. Likewise, Mark Johnson and George Lakoff (2002) refute separation of mind and body. Their theory of language suggests that our conceptual system rests on embodied metaphors (as opposed to metaphors resting on a conceptual system).[3] They argue that meaning is implemented through "embodied organism-environment interactions", as opposed to severed ontological truths (p. 249).

Esther Thelen (2000) agrees that "the mind simply does not exist as something decoupled from the body and the environment in which it resides" (p. 7). She rejects the old paradigm in which physical and cognitive development results from autonomous maturational changes (e.g., hierarchical executive functions). She instead describes physical and cognitive development through a dynamic systems perspective (see Spencer et al., 2006, for a review of Thelen's work). Thelen provides four pillars of consideration for studies of cognitive and behavioural development (Spencer et al., 2006, p. 1533):

1. emphasis on longitudinal change ("behavior emerges in the moment, but the effects of each behavioral decision accumulate over longer time scales, as each change sets the stage for future changes")
2. emphasis on complex systems ("behavior is multiply determined and softly assembled from the nonlinear interactions of multiple subsystems")

[2] "Such models define word meanings in terms of other symbols, producing circular definitions much like those found in a dictionary" (Roy, 2005, p. 389)
[3] Examples of conceptual metaphors, and the precedence of embodiment, include: orientational metaphors (up = more); structural metaphors (seeing = understanding); and ontological metaphors (physical entities = ideas) (Lakoff & Johnson, 1980)

3. emphasis on embodiment (“perception, action, and cognition form an integrated system that cannot be partitioned”)
4. emphasis on individuality (“development happens in individual children solving individual problems in their own unique ways”)

In Thelen’s view, an individual’s behaviour (including cognition) emerges from a unique confluence of situated and embodied conditions that occur over extended periods of time. Dynamic systems perspectives challenge assumptions of fixed traits and innate abilities.

Taking an extreme environmental position, K. Anders Ericsson (2007) refutes entirely the notions of innate skill and of biologically determined “upper limits” to skill acquisition. Other than the mediating factors of height and body size, Ericsson finds a severe paucity of evidence for genetic determinants of expert performance in physical and mental activities. Of the evidence that does exist, Ericsson argues that “heritability does not imply immutability or unchangeability” (p. 36). “That growth and improvement occur after maturity implies that developmental capacities must certainly not be the sole causal agent and may be less relevant to improvement than is often assumed” (p. 41). Deliberate practice is a more parsimonious explanation for talent than is innateness. Motivated individuals often improve performance beyond theoretical upper limits through challenging work. For example, with concentration, problem-solving, and hundreds of hours of practice, an individual can remember 80 random digits (70 standard deviations above Miller’s magical 7 +/- 2) (p. 4). Ericsson encourages “a deeper understanding of human potential and how it can or cannot be attained by motivated efforts to improve” (p. 45).

Further supporting the possibilities of skill acquisition beyond childhood, the previous two decades have produced an explosion of neuroscience evidence that adult brains can change throughout life (e.g., van Praag, 2008). This includes: structural changes (i.e., dentritic or axonal growth), changes in neurochemical activity (e.g., differential production of specific neurotransmitters), metabolic changes (e.g., oxygen uptake), and neurogenesis (development of new neurons). These discoveries put to rest popular assumptions that the adult brain is "hard-wired", which suggests heretofore unacknowledged resilience of individual competencies (e.g., Doidge, 2007). As an example, stroke victims now enjoy greater recovery from paralysis through constraint-induced movement therapy, in which the "good" side of the body is restrained, forcing patients to exercise the "bad" side, which leads to visible cortical reorganization (the brain is rewired) and reacquisition of muscle control. Without deliberate and challenging exercise, the bad side fails to improve, which reinforces beliefs that the brain cannot be changed. On the other hand, motivational support for deliberate and challenging practice, despite prevailing beliefs, may provide a key to overcome learned limitations.

The design of educational interventions benefits from judicious identification of experiences that cultivate biological faculties. We know that enriched environments can stimulate well-being and brain growth (e.g., Gray, 2002), that biofeedback of brain rhythms can encourage self-regulation and neuronal changes (Ros, Munneke, Ruge, Gruzelier & Rothwell, 2010), and that attentional skills cultivated through video game play may counter-intuitively generalize to other contexts (Bavelier, Green & Dye, 2010). The Arrowsmith School employs a number of challenging training interventions to amend learning disabilities often thought to be insurmountable (Doidge, 2007). All of these interventions emphasize deliberate practice against prevailing norms.

Understanding how experiences modify the brain can also provide insight into the relationship between cultural and biological evolution. In their overview of evidence supporting the interaction of culture and brain, Kitayama and Uskel (2011) discuss "scripted behaviour" (behaviour that is filtered through and normalized by an evolving "collective-level reality of culture"). In brief: in order to establish a respectable identity within a particular community, an individual both inherits cultural values and chooses from cultural practices. Brains are changed as a result of repeated and sustained behaviours. These changes influence beliefs, which in turn feed back into cultural values. The dynamic interaction between experience, belief, and biology appears to be a ripe field of research.[4]

The aforementioned research challenges assumptions that skills are innate. A variety of feedback loops affect learning. Even critical periods (e.g. for language learning) are challenged: adults might acquire skills at rates similar to children; however, adult responsibilities, lifestyles, and beliefs may serve as obstacles to freedom and necessity of attentiveness. In terms of the present research, treating TA as a fixed personality trait appears unwarranted and deleterious.

***Personality Research Requires Multiple Perspectives***

A complex understanding of any phenomenon demands interdisciplinary perspectives, including biological, ecological, and agentive theories. Such complexity has yet to find consensus in the domain of personality research: the domain today appears

[4] "Explicating this dynamic is going to be a massive research endeavor that can only be achieved through extensive interdisciplinary collaboration." (Kitayama & Uskel, 2011, p. 443)

pre-paradigmatic. A scientific paradigm is achieved when researchers work to refine existing theories, united by shared language and reliable exemplars. In contrast, in a pre-paradigmatic state, we expect a sprawling, confusing, often contradictory research corpus that emerges from competing theories and different schools of thought. While messy, these varied descriptions of available phenomena represent a necessary step on the road to a paradigm, assuming a paradigm is possible.[5]

Two competing models of personality have been nominated as possible paradigms: Eysenck's three-factor PEN model[6] and Costa and McCrae's big Five Factor Model (FFM)[7]. Each of these models attempts to reduce personality to a set of stable traits. Predictive significance in the PEN model has been replicated through hundreds of analyses by a variety of researchers across the world (Eysenck, 1983, 1991). However, critics charge that PEN is not broad enough; for example, it neglects traits related to openness to experience[8] (Costa & McCrae, 1992, p. 861). The FFM fills this gap, and an explosion in research using the FFM model suggests it has greater community support than PEN (John & Nauman, 2010). However, the FFM also has critics. Block (2010) argues that its factors are subjectively derived and subjectively interpreted; its cumulative scoring techniques neglect non-linear and complex correlations; and, perhaps most relevant, it ignores contemporary theories of evolution.

[5] The concept of a paradigm is generally accepted, though not entirely understood. When he introduced the idea of scientific paradigms in 1970, Kuhn was referring mainly to the pure sciences (for example, astronomy, physics, biology). With respect to the social sciences, he remained cautionary: "it remains an open question what parts of social science have yet acquired such paradigms at all. History suggests that the road to a firm research consensus is extraordinarily arduous." (p. 15). Nevertheless, today, innumerable peer-reviewed articles allude to paradigms within the social sciences; for example: Eysenck (1997), Glăveanu (2010), Tang (2010).

[6] The PEN model's three factors: psychoticism, extraversion-introversion, and neuroticism

[7] The Five Factor Model's five factors: conscientiousness, agreeableness, neuroticism, openness, extraversion-introversion

[8] TA is sometimes related to openness to experience (for example, by: McCrae, 1996; Hunter, 2006; Zhao & Seibert, 2006; Bardi, Guerra & Ramdeny, 2009)

In light of evolution, some researchers appear dissatisfied with all personality theories that purport trait stability. For example, Borghans, Duckworth, Heckman, and Weel (2008) dispute the economic and psychological value of trait measurements because “cognitive and personality traits evolve, albeit at different rates at different ages” (p. 1036). Norem (2010) writes that “defining personality exclusively in terms of traits ignores entire categories of structures and processes” (p. 65). Van Egeren (2009), who recognizes that self-regulation is obscured by traditional models, uses a cybernetic model to clarify the ongoing feedback within personality development.

Walter Mischel’s research concerning personality has proven especially insightful to me. For several decades, he has advocated for a dynamic understanding of personality, yet Mischel (2009) describes firsthand how his own seminal work has been haphazardly misrepresented, fuelling a futile debate between those who emphasize innate causes versus those who emphasize situational causes (reminiscent of the nature versus nurture debate). For Mischel, personality is dynamic, requiring innate, ecological, as well as agentive explanations. Mischel (1973) warns that confusion arises when researchers fail to understand that the same behavioural phenomena must be interpreted from these three perspectives:

1. with respect to the *theoretical personality constructs* that are expected to mediate behaviour
2. with a focus on *ecological conditions* that elicit behaviour
3. with a focus on the *subjective (phenomenological) experience* of behaviour

A future paradigm in personality research, Mischel says, would benefit from the permanent merger of all three perspectives, rather than isolated analysis of one or the other perspectives. In my review of the TA construct, below, I find little evidence of this merger.

As an example of using these three perspectives, consider Mischel's famous "marshmallow experiment", which significantly predicts future success for four-year olds who do or do not resist eating a marshmallow in a controlled setting (Mischel et al., 2011). At a theoretical level, some might assume an innate predisposition to self-regulation. From an environmental perspective, we might concentrate on situational affordances that affect behaviour (for example, parenting style or poverty levels). Finally, from a subjective perspective, learners themselves may wonder (consciously or not): what can I do to help myself from eating that marshmallow? In fact, all three questions are relevant and must be examined in tandem for a rich explanation of the phenomena. The agentive question, in particular, is perhaps most interesting to educators and psychologists who emphasize self-regulation.

Can four-year olds develop the self-regulation to resist eating marshmallows? According to Mischel et al. (2011), there is hope: "at least in laboratory situations, it is possible to dramatically enhance this ability [to delay gratification] through the use of relatively simple attention control and cognitive re-appraisal manipulations" (p. 255). For example, children can be taught simple metacognitive techniques to enable them to subjectively cool the hot stimulus that tempts premature reaction (e.g. "imagine a picture frame around the marshmallow"). Future research is required to determine if and how such simple strategies will generalize across situations and time.[9] Mischel et al (2011) remain optimistic: "Ultimately, it may be possible to target and harness the underlying

[9] "Time on task" is likely to be a critical predictive factor; it is generally accepted that the more that skills and strategies are exercised, the more likely they are to be available to individuals in times of need.

mechanisms into readily teachable interventions to achieve sustained and consequential behavior change" (p. 255). If educators can help children to develop self-regulation, then, turning to the present research: can educators help adults to develop tolerance of ambiguity?

The theoretical assumptions that I invoke, above, emphasize the vitality of experience in the cultivation of knowledge. Conceptual learning can occur throughout life; culture dynamically feeds back into learning. Values and expectations are limiting factors. I intend to examine claims concerning these two social science constructs, TA and ET, using various levels of analysis. To achieve greater consensus on the meaning of these constructs, I believe we must continue to describe them. The dialogue begins with sensitive attention to different interpretations of each phenomenon.

## What is Tolerance of Ambiguity?

Tolerance of ambiguity (TA) refers to an individual's ability to engage with multiple interpretations of a perceptual phenomenon. A perceptual phenomenon refers to any object that can be grasped mentally. This includes both material and conceptual objects. Because objects of perception can very often be interpreted in multiple ways, the ability to tolerate the ambiguity of an object potentially leads to new insights and knowledge about it.

The dominant theory of TA idealizes it as a stable personality trait. This position itself appears to lack TA: it omits interpretations that are required for robust personality research (e.g., Mischel's multiple perspectives: theoretical, environmental, and subjective). The dominance of this theory is due in part to its inception in the mid-twentieth century, when normal science held that adult brains were "hard-wired". In contrast to the dominant position, I argue for the less common theorization whereby TA is interpreted not merely as a trait, but also as a skill. As such, TA is situated within a metacognitive process that can be modelled and exercised. Unlike conventional traits, such as eye colour, TA is subject to change. TA is affected through time by complex systems of feedback that implicate trust and sensitivity. Individuals and environments can potentiate TA. In this sense, TA belongs in the realm of educational technology.

I support my position based on a review of literature related to TA. In the first sub-section, below, I introduce the TA concept as well as its ambiguity. The second sub-section contains a brief historical review of the concept. I begin in early twentieth century, when variable responses to ambiguous phenomena indicated individual differences in perception yet deemphasized agency. Frenkel-Brunswik hypothesized TA as an emotional variable that may distort perception. Her hypothesis lacked evidence yet gained reputation through its association with Authoritarian Personality Theory. Authoritarianism derives from Adorno's critical analysis of "excessive rationality", which prefigures modern models of cognitive bias: a tendency to submit to dominant and accessible interpretations of phenomena that are otherwise too complex to fathom. Budner, the next major figure in the history of TA, attempted to clarify TA's construction as a measurable personality variable. Subsequent researchers propose a variety of subtle conceptual differences, which has led to numerous TA measurements and a lack of research cohesion. My historical description concludes with a review of contemporary applications of TA, highlighting continued interest in the construct from researchers in many fields in spite of TA's problematic construction. Next, I summarize the two major theorizations of TA that the literature reveals: TA as a trait and TA as a skill. Finally, I advocate for a theorization of TA that includes all three of Mischel's perspectives, a theorization that potentially renders TA into an educational resource.

***Tolerance of Ambiguity – Literature Review***

**Introduction: the ambiguity of "tolerance of ambiguity".**

Tolerance of ambiguity (TA) is itself an ambiguous concept. One requires a tolerance of ambiguity in order to appreciate its treatment across historical and contemporary academic research. Different researchers interpret TA in different ways. The literature reveals various interpretations and criticisms. Yet the construct remains popular, a testament to its perceived utility.

Three themes emerge from a review of the literature: TA as a general personality trait, TA as a content-specific construct, and TA as a metacognitive process. These interpretations bear resemblance to the three perspectives advocated by Mischel: TA as a theoretical personality construct; TA as a situation-specific disposition; and TA as a phenomenological experience. One problem, however, is that most researchers fail to integrate these interpretations.

TA is predominantly described as a general personality trait: a fixed and stable independent variable (for example: Arquero & McLain, 2010; Atef-Vahid, Kashami & Haddadi, 2011; Benjamin, Riggio & Mayes, 1996; Endres, Chowdhury & Milner, 2009; Geller, Tambor, Chase & Holtzman, 1993; Hartmann, 2005; Hazen, Overstreet, Jones-Farmer & Field, 2012; Hunter, 2006; Kajs & McCollum, 2010; Marzban, Barati & Moinzadeh, 2011; Norton, 1975; Quillin et al., 2008; Ruch & Hehl, 1983; Zenasni, Besançon & Lubart, 2008; Zhu, Xie & Xie, 2012). Some researchers extend the theoretical definition of TA to consider also environmental factors; at this level, researchers acknowledge that an individual's TA in one domain or against specific content may not generalize to another domain or content (e.g., Bardi, Guerra & Ramdeny, 2009; Durrheim & Foster, 1997; Ely, 1989; Kenny & Ginsberg, 1958). Finally, some researchers inquire into the subjective experience of TA, contemplating it as a skill (Banning, 1993; DeRoma, Martin & Kessler, 2003; Furnham & Ribchester, 1995; Levitt & Jacques, 2005; Merenlouto & Lehtinen, 2004; Wayne et al., 2011). In this conception, TA is treated also as a dependent variable: identical content may elicit different TA responses in the same individual depending on other factors (e.g., sensitivity to novel aspects of a phenomenon; trust to overcome cognitive conflict). Theorizing TA as a skill situates it in the realm of metacognition. This interpretation provides TA with its most robust construction: acknowledging personality and ecology, as well as agency and evolution.

As a skill, TA overcomes some of the problems that are apparent in trait interpretations. For example, conceived as a skill, TA is expected to be variable. Meanwhile, conceived as a trait, TA is expected to exhibit stability. However, exhibitions of theoretical stability are elusive. Lack of apparent stability is due in part to inconsistent criteria. Researchers do not appear to agree on the characteristics of theoretical stability. Different proponents of trait theories suggest different behaviours against which to validate the construct. Furthermore, some researchers see the trait as uni-dimensional while others suggest numerous sub-factors (implying that TA measures several personality characteristics, not one). Researchers correlate TA to other constructs inconsistently. Researchers are further challenged by a wide variety of TA measurements, mostly pencil-and-paper tests, which draw competing criticisms concerning content, criterion, and construct validity. These differences are described in more detail in the sub-sections, below.

Table 1. *TA Label Variations and Usage*

| Label | Reviewed articles | Scopus search hits[a] |
|---|---|---|
| tolerance of ambiguity | 70 | 134 |
| tolerance for ambiguity | 58 | 127 |
| intolerance of ambiguity | 65 | 126 |
| intolerance for ambiguity | 10 | 11 |
| ambiguity tolerance | 59 | 73 |
| ambiguity intolerance | 14 | 20 |
| tolerance-intolerance of ambiguity | 8 | 6 |

*Note.* [a] search results retrieved September 30, 2012

Further complicating the TA literature, a variety of labels ostensibly refer to the same phenomenon. Table 1 contains a list of labels for this construct, as well as rudimentary indications of each label's popularity based on appearances in articles that I reviewed and in search results from the Scopus psychology database. Differences in labels do not appear to designate clearly differentiable definitions of the construct. The various labels for TA are used interchangeably when researchers cite one another's work; for example, "the concept of ambiguity (in)tolerance or its equivalents" (in Arquero & McLain, 2010, p. 477). The various labels are typically traced to the same origins, in particular: Frenkel-Brunswik (1949), Adorno et al. (1950), and Budner (1962). The construct always refers to a bipolar spectrum of tolerance-intolerance: early researchers emphasize “intolerance”, while most contemporary researchers emphasize “tolerance”. In popular parlance, tolerance connotes “begrudging acceptance”, yet within this literature it generally means “attraction” (e.g., Budner, 1962, McLain, 1993). This anomalous meaning of tolerance may further contribute to research confusion (e.g., according to Kirton, 1981, p. 408). I use the label “tolerance of ambiguity” throughout this paper. I make note of labelling differences across researchers throughout this review.

**Historical review of tolerance of ambiguity.**

***Early research on individual differences in response to ambiguous stimuli.***

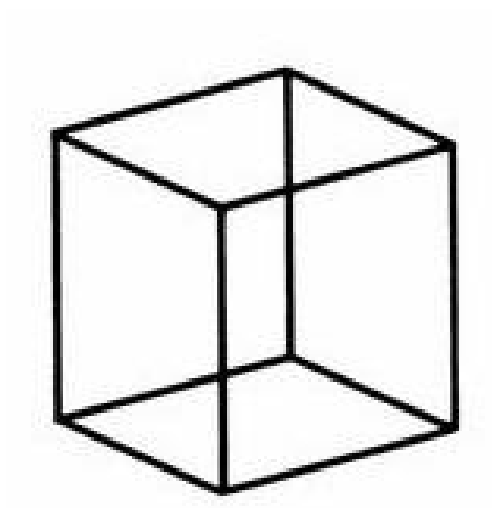

*Figure 2.* Necker cube: a multistable figure; its orientation spontaneously fluctuates.

William McDougal (1926) hypothesized that individuals may perceive differing rates of fluctuation when viewing a multistable figure such as a Necker cube (see Figure 2). A multistable image lacks a single unique interpretation; it typically fluctuates between possible interpretations. McDougal thought that the rate of fluctuation depended on the individual’s level of introversion-extroversion. Introverts were hypothesized to experience more fluctuations; extroverts fewer fluctuations. McDougall further hypothesized that individual differences could be exacerbated by drugs that induce introversion or extroversion. Upon testing McDougall's theories, Guilford and Braly (1931) rejected the first hypothesis concerning individual perceptual differences, but retained the second hypothesis, concerning perceptual differences due to drugs.

A few years later, Sherif (1935) investigated response to autokinesis, a phenomenon whereby a stationary point of light in a dark environment (such as a star in the night sky) will appear to move or flicker at varying rates. In purely objective terms, no movement or flickering takes place. However, Sherif demonstrated that, when tested in a group, individuals will conform to a group judgement concerning the amount of (imaginary) movement that took place.

In theory, visual perception involves more than absorption of light waves; perception is not a simple and objective recording of reality. McDougall and Sherif correctly recognize individual differences in perception. McDougall's work stresses perceptual contexts (e.g. the effect of drugs). It resembles psychophysics, a quest to quantify the correlation between psychological (subjective) and physical (objective) events. Sherif's work stresses social contexts, foreshadowing Asch's famous experiments in group conformity. However, while personality and social contexts are considered, the role of individual motivation is neglected.

***Frenkel-Brunswik and the birth of the TA construct (1949).***

Frenkel-Brunswik was interested in the role of motivation on perception. In her exploration of perception, she seized upon the psychoanalytic concept of "emotional ambivalence", that is, "the coexistence, in the same individual, of love- and of hate-cathexis toward the same object" (Frenkel-Brunswik, 1949, p. 115). Psychoanalytic theory suggests that, if an individual cannot admit to his mixed feelings, then the ambivalence becomes repressed. In such a case, the individual overcompensates by expressing only love or only hate toward the relevant object. As a result of the ambivalence, he inevitably distorts his picture of reality.

Frenkel-Brunswik recognized problems with scientifically validating psychoanalytic concepts (e.g., lack of falsifiability). So, she sought behaviourally observable factors that could be formalized. She began with the psychoanalytic hypothesis that a repressed ambivalence manifests cognitively as a rigid and inadequate perception of reality (Frenkel-Brunswik, 1949, p. 115). In her exploratory work, she asked: Are some people less likely to face their mixed feelings in general? Do these individuals rigidly adhere to particular perceptions? Does this rigidity generalize to non-emotional stimuli?[10] Can we test for it? She hypothesized that this personality type, if it exists, possesses an “intolerance of ambiguity”, characterized as “a tendency to resort to black-white solutions, to arrive at premature closure as to valuative aspects, often at the neglect of reality, and to seek for unqualified and unambiguous over-all acceptance and rejection of other people” (p. 115). She suggested her hypothesis could be investigated by objectively examining response patterns to external conditions of ambiguity.

Frenkel-Brunswik proposed several tests to investigate tolerance-intolerance of ambiguity. In one test (similar to McDougall’s Necker test), rigid personalities were expected to report fewer and less frequent fluctuations of an ambiguous figure. In another test, in which participants are shown a series of images whereby a dog gradually transforms into a cat (see Figure 3), rigid personalities are expected to retain their initial image of the dog farther into the series, avoiding the emergent cat. In a third test, after

[10] Unlike future researchers (e.g., Budner, 1962, MacDonald, 1970), Frenkel-Brunswik equates ambiguity tolerance with rigidity: “It is this rigid adherence to norm which furnishes the key to an understanding of all the various avoidances of ambiguities listed in this paper” (Frenkel-Brunswik, 1949, p. 119)

solving a series of problems using the same repetitive, long and complex method, participants are given a new series of problems that can be solved using a much easier method. Rigid personalities are expected to continue using the long and complex method, despite its dispensability. In operational terms, based on these tests, the individual who is intolerant of ambiguity will demonstrate: (a) a relative inability to perceive an objectively ambiguous situation, (b) a relative inability to alter a response pattern to an objectively changing situation, and/or (c) a maladaptive response pattern, that is, a rigid adherence to a previously learned response even when it is no longer optimal.

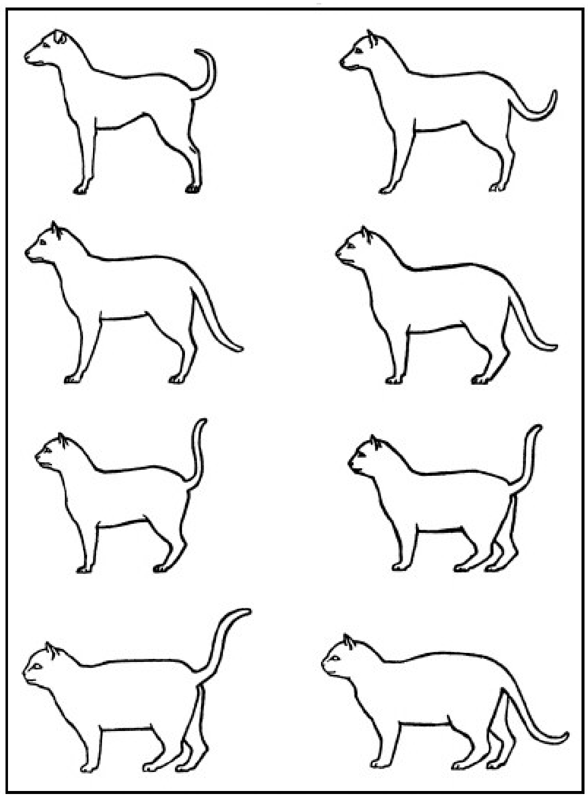

*Figure 3.* Dog-Cat Test of Intolerance of Ambiguity. Adapted from *The Psychology of Politics*, by H. Eysenck, 1954, p. 223. Copyright 1954 by Routledge. Image retrieved 2012-08-03 from books.google.com: http://bit.ly/Mij4QH

Frenkel-Brunswik aimed to explore emotionally motivated limits to perception that could lead to inadequate pictures of reality. While she proposed theoretical tests, she remained cautious. For example, Blum (1959), who used a modified version of the Dog-Cat test in his research, mentions (in a footnote) personal correspondence with Frenkel-Brunswik who said that she was "not ready to distribute" this "exploratory" work (p. 299). Nevertheless, both Eysenck (1954) and Blum proceeded to use the Dog-Cat test.

Frenkel-Brunswik explicitly states that she set out to investigate "the generality or lack of generality of the personality patterns" that involved intolerance of ambiguity; she drew no overt conclusion (Frenkel-Brunswik, 1949, p. 112). As noted by Durrheim and Foster (1997), it appears that many subsequent researchers charged ahead under the assumption that the TA construct is generalizable: "Whereas Frenkel-Brunswik's 'prime concern' was to test whether ambiguity tolerance[11] is generalized across different social objects, this has typically been assumed" (p. 741). This premature generalization appears due in part to TA's association with a popular, politically motivated project: authoritarian personality theory.

***Authoritarian personality theory and excessive rationality (1950).***

Frenkel-Brunswik's conception of intolerance of ambiguity is often traced back by subsequent researchers (e.g., Arquero & McLain, 2010; Durrheim, 1998; Geller et al., 1993; MacDonald, 1970; Rydell & Rosen, 1966; Sallot & Lyon, 2003; Van Hiel, Onraet & De Pauw, 2010) to *The Authoritarian Personality* (Adorno et al., 1950). This popular text was published in the wake of World War II as academics scrambled to understand the "fascist personality type", because many Nazis claimed they were "just following orders", which was a troubling sentiment. Its first author, Theodor Adorno, was a leader of the Frankfurt School, an influential group of critical social theorists (for an overview, see, Zuidervaart, 2011). According to my interpretation, Adorno (e.g., in Adorno &

[11] Durrheim & Foster switch to use the "ambiguity tolerance" label.

Crook, 1994, p. 22) suggested that excessive rationality (as expressed, for example, in capitalism) breeds weak characters that are highly dependent on authoritative reason. Excessive rationality refers to a type of thinking in which the ends justify the means (the goal is prized regardless of its cost). Such an excess of rationality can sometimes be reinterpreted as *lacking* rationality (if it turns out that the cost outweighs the goal). Adorno implies that a weak character is wilfully oblivious to an excess of rationality (and its implicit lack of rationality) due to the complexity involved. For a variety of hypothetical reasons (including culture and upbringing), the weak character rigidly abstains from inquiry, instead relinquishing judgement to a perceived authority figure. In the case of the obedient Nazi, he works diligently toward authoritative goals, despite the wickedness of the means. In the case of capitalism, Adorno suggests that our culture is so complex that we are all weak characters, overly dependent on authoritative reason.

Adorno's theory of excessive rationality foreshadows modern theories of cognitive bias, albeit at a more political level of analysis. As a contemporary example, consider our industrial practice of agricultural monoculture (when a single crop is sown over large areas of land, year after year). This practice yields immense quantities of prized crops (of which we partake daily, largely without question). The practice of monoculture is driven by readily available economic and technological incentives, which appear rational in the short-term (food arrives in our grocery stores cost-effectively and dependably). However, longer-term consequences, which are hard to predict, may harbour hidden costs that render the initial cost assumptions problematic (lacking rationality). For example: monocultures are more vulnerable to diseases (Zhu, 2000) and monocultures may contribute to the collapse of bee colonies (Nicholls & Altieri, 2012).

These hard-to-predict long-term consequences lead to increasing dependence on technological interventions (genetic modifications to stave off disease; seasonal bee importations to achieve requisite pollination), which represents another set of excessively rational decisions that could be reinterpreted as lacking rationality (if and when we reassess those decisions).

Authoritarian personality theory spawned a vast body of research, including tests for rigidity and ambiguity tolerance designed to reveal anti-Semitic, ethnocentric, politically conservative, and fascist tendencies. Proponents hoped to use these personality inventories to intervene against prejudice. Critics point out that the authoritarian personality theory is itself intolerant of ambiguity: it is "a vast oversimplification … all the 'baddies' (authoritarians, racists, anti-Semites, conservatives, punitive people, rigid thinkers) are conveniently shown to be essentially all the same" (Ray, 1987, p. 559). As a result of correlating specific ideologies to irrationality, the authoritarian personality theory can be construed as a politically motivated project, rather than a scientific one (Durrheim, 1998; Jost et al., 2007; Van Hiel et al., 2010). Nevertheless, when considered apolitically, Adorno's critical theory deserves attention: an inability to cope with complexity may engender cognitive bias: premature confirmation, over-dependence on readily available and authoritative interpretations, and ignorance of underrepresented excesses of rationality.

***Budner's elaboration of TA (1962).***

Stanley Budner (1962) recognized that TA had become mired in political ideology. Returning to Frenkel-Brunswik's initial hypothesis, Budner investigated TA as a personality trait related to perceptual evaluation. Unlike his predecessors (e.g., Frenkel-

Brunswik, 1949; Adorno et al., 1950; Eysenck, 1954), Budner explicitly differentiated TA from rigidity. Budner claimed that rigidity is a behavioural constant, not a perceptual evaluation (i.e., when an alternate interpretation is present, the rigid personality might see it yet refuse it, while the low TA individual might be unable to see it yet able to accept it once it is seen). Budner's formal treatment of TA included a detailed definition and a popular measurement.

Table 2. *Proposed Threat-responses to Ambiguous Situations (Budner, 1962)*

| | Submission to stimulus | Denial of stimulus |
|---|---|---|
| Phenomenological response | Discomfort | Repression |
| Operative response | Acts of avoidance | Acts of destruction or reconstruction |

Budner (1962) defined intolerance of ambiguity as "the tendency to perceive (i.e. interpret) ambiguous situations as sources of threat" (p. 29). He identified three categories of ambiguous situations: those characterized by *novelty* (e.g., a completely new situation with no familiar cues), by *complexity* (e.g., a complex situation with a great number of cues), or by *insolubility* (e.g., a contradictory situation in which different elements or cues suggest different structures). He identified four indicators of an individual's perception of threat (see Table 2): phenomenological submission (discomfort), phenomenological denial (repression), operative submission (avoidance behaviour), and operative denial (destructive or reconstructive behaviour) (1962, p. 29). At the other end of the spectrum, Budner defined "tolerance of ambiguity" as "the tendency to perceive ambiguous situations as desirable". Regrettably, Budner did not elaborate on indicators of "desirable" responses, which poses a problem for subsequent researchers who may interpret "tolerance" in different ways (Kirton, 1983, p. 408).[12]

Critically, although Budner recognizes phenomenological responses, he did not pursue the mutability of these responses. In other words, he emphasizes subjective experience yet de-emphasizes subjective agency. He treats TA as a disposition: "each person has his own individual way of contending with himself, the environment, and the frustrations which the interaction of the self and the environment necessarily entail" (p. 48). He suggests that TA does not "lead" to behaviour; rather, behaviour is a manifestation of TA ("Being intolerant of ambiguity does not lead an individual to favour such things as censorship, rather, favoring censorship (in most situations) is part of being intolerant of ambiguity", p. 49). He neither investigates nor encourages investigation of how TA can be shaped through educational or phenomenological intervention.

Budner's 16-item Likert test to measure tolerance-intolerance of ambiguity appears to be the most popular instrument in the field (Bors, Gruman & Shukla, 2010; Furnham & Ribchester, 1995; Geller et al., 1993; Grenier, Barrette & Ladouceur, 2005). For criterion validity, Budner identified significant correlation with: social beliefs and behaviours (e.g., conventionality, religious conviction, and attitude toward censorship), personal values (e.g., authoritarianism, Machiavellianism, idealization of parents), and career choice (specifically, medical school students' choice for structured versus unstructured fields – e.g., surgery versus psychiatry). Despite its popularity, the instrument has received considerable criticism, reviewed in the following sub-section.

[12] Characterizing individuals as "receptive" to ambiguity is worthwhile. However, I agree with Kirton's assessment: tolerance commonly connotes "indifference" rather than "desire". Budner's use of the term appears to complicate the construct.

***Measurements (1952 – present).***

Many instruments to measure TA have been developed. While the tests reveal various subtle differences in conceptions of TA, all of these tests assume measurement of a personality trait. The trait can then be used as an independent variable in subsequent research (correlating TA against a dependent variable). Some tests assume that the trait should vary across situations or content types. No test is designed specifically to monitor changes in TA within a situation or content type.

Early tests were designed for controlled settings (for example, laboratory examinations of individual responses to Necker Cubes, Dog-Cat images, and autokinesis); these do not generalize well to everyday situations (Bruner & Goodman, 1947). Subsequent tests rely mainly on self-report via paper-and-pencil questionnaires. These pencil-and-paper TA tests appear to measure different factors (Bors et al. 2010; Furnham & Ribchester, 1995). They do not correlate with one another (Bors et al., 2010; Furnham & Ribchester, 1995; Kenny & Ginsberg, 1958; McLain, 2009). When investigated individually, they appear psychometrically dubious (Bors et al., 2010; Furnham & Ribchester, 1995; Grenier et al., 2005; Kirton, 1981; McLain, 2009; Norton, 1975). Several researchers suggest that inconsistencies in TA research are a result of incompatible measures (Furnham, 1994; Herman, 2010) and "the historical widespread use of the Budner scale" (Bors et al., 2010, p. 243). The following list contains brief qualitative reviews of some of these instruments, revealing chequered characterizations of the TA construct:

- *Walk's A Scale (O'Connor, 1952)*
    - Used by: Eysenck (1954), Budner (1962)

  - Probably the earliest paper-and-pencil survey; designed to measure "dichotomizing tendencies", that is, the inability to see things in more than one way at once (Kenny & Ginsberg, 1958)
  - MacDonald (1970) cites "virtually no internal consistency" (p. 792)
  - Furnham (1994) challenges O'Connor's claim of unidimensionality, suggesting factors related to "wise actions", "adopting alternative responses", "rather conservative points of view" (p. 407)
- *Intolerance of Ambiguity Scale (Coulter, 1954)*
  - Used by: Eysenck (1954), Budner (1962)
  - Designed to measure rigidity, prejudice, and ethnocentricism (Eysenck, 1972)
  - According to Kenny and Ginsberg (1958), the correlation between the Dog-Cat test and Coulter's test is "the only available evidence of a positive relationship between various tests of intolerance of ambiguity" (p. 301)
- *Scale of Tolerance-Intolerance of Ambiguity*[13] *(Budner, 1962)* (see above)
  - Used by: Norton (1975); Sidanius (1978); Rotter and O'Connell (1982); McLain (1993); Dollinger, Golden, and Saxton (1997); Fibert and Ressler (1998); Chen and Hooijberg (2000); Banning (2003); Bakalis and Joiner (2004); Clampitt and Williams (2007); Endres et al. (2009); Wayne et al. (2011)
  - Chen and Hooijberg (2000) believe that Budner's operationalization of ambiguity "best captures the complex situation of diversity" (p. 2399)
  - Sidanius (1978) suggests Budner's scale contains not one but five factors, related to: racism, political-economic conservatism, religion, sexual repression, and

[13] Also referred to as Budner's "Intolerance *for* Ambiguity" Scale (see, for example: Rotter & O'Connell, 1982; Geller et al, 1993; Benjamin et al., 1996;)

authoritarian aggression (p. 219). Furnham's (1994) analysis reveals a four-factor structure, with factors related to: predictability, variety and originality, clarity, regularity. Benjamin et al. (1996) refute Budner's single-factor structure but are unable to replicate Furnham's four-factor structure. Durrheim (1998) suggests that Budner's scale is limited to a single factor related to political conservatism (p, 744).

- Lack of internal reliability and/or lack of evidence of validity are declared by Norton (1975), Ray (1988), Geller et al. (1993), Benjamin et al. (1996), McLain (2009) and Bors et al. (2010), who also suggests poor representation of theory
- Sidanius (1978), Yurtsever (2000) and Chen and Hooijberg (2000) suggest that low internal reliability is expected because the scale is multi-dimensional. Sidanius (1978) suggests a better indication of reliability is test-retest reliability, for which Budner's scale is respectable.
- Ray (1987) suggests that intelligence is a confounding factor. Benjamin, Riggio and Mayes (1996) and Bors et al. (2010) reveal that verbal ability acts as a confounding factor. In both Ray's (1998) and Bors et al.'s (2010) analysis, positive-coded items are not related to negative-coded items.

- *Tolerance of Ambiguity Scale*[14] *(Rydell & Rosen, 1966)*
  - Used by: Houran and Lange (1996); MacDonald (1970)
  - Rydell and Rosen (1966) admit that they constructed the scale without resorting to experience (on an a priori basis)
  - MacDonald (1970) finds it to be a valid measure, yet adds four questions to increase reliability

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[14] MacDonald (1970) refers to this as "the Rydell-Rosen *Ambiguity Tolerance* Scale"

  - Norton (1975) and Geller et al. (1993) suggest it lacks internal reliability and lacks evidence of validity
  - Furnham (1994) refutes unidimensionality and proposes six factors, related to: problem solving, anxiety, desire to complete, adventurousness, uncertainty seeking, problem fragmentation
- *Revised Scale for Ambiguity Tolerance*[15] *(AT-20) (MacDonald, 1970)*
  - Used by: Tsui (1993); Owen and Sweeney (2002 WP); Sallot and Lyon (2003); Hartmann (2005); Litman (2010); Zhu et al. (2012)
  - MacDonald cites limitations with Walk's A Scale, Budner's Scale of Tolerance-Intolerance of Ambiguity, and Rydell and Rosen's Tolerance of Ambiguity Scale, as impetus for creating a new scale
  - MacDonald correlates for criterion validity against existing measures of dogmatism and rigidity, and for construct validity against behaviours including church attendance and performance on a scrambled words task
  - Norton (1975) and Geller et al. (1993) question its reliability and validity
- *Measurement of Ambiguity Tolerance*[16] *(MAT-50) (Norton, 1975)*
  - Used by: Bennett, Herold, and Ashford (1990); Anderson and Schwartz (1992); Kajs and McCollum(2010)
  - Norton correlates for criterion validity against Budner's scale, as well as against scales for rigidity and dogmatism; for construct validity against willingness to volunteer for ambiguous situations, aesthetic judgements, and verbal behaviours

[15] MacDonald's (1970) label represents an early shift toward referring to this construct as "ambiguity tolerance", though he clearly builds on Walk, Budner, Rydell and Rosen, and others. Numerous subsequent researchers follow suit: Norton (1975), McLain (1993), Durrheim and Foster (1997).

[16] In the title of his article and scale, Norton uses the term "ambiguity tolerance", but he uses "intolerance of ambiguity" when defining the term (in the same article).

  - Norton targets eight factors (related to: philosophy, interpersonal communication, public image, job-related, problem-solving, social, habit, art forms)
  - Kajs and McCollum (2010) see Norton's scale as "a strong measure in quantifying TFA"[17] (p. 79)
  - Geller et al. (1993) suggest it is "flawed by inadequate evidence of reliability and validity" (p. 990)
- *Tolerance for Ambiguity Scale*[18] *(Geller et al., 1993)*
  - Used by: Quillin et al. (2008); Trottier et al. (2012)
  - Designed to measure TA in physicians
  - Contains items from Budner, MacDonald, and Norton
- *Multiple Stimulus Types Ambiguity Tolerance scale (MSTAT-I)*[19] *(McLain, 1993)*
  - Used by: DeRoma et al. (2003)
  - McLain correlated against tests for: risk-taking, dogmatism, and receptivity to change; and validated it against Budner's and MacDonald's tests
  - Bors et al. (2010) suggest that McLain's test measures a different construct compared to Budner's test, and that McLain's test has better validity compared to Budner's
  - McLain treats TA as a single factor, but Herman (2010) suggests multi-dimensionality due to low factor loadings across the 22 test items
  - McLain explicitly addresses different content types (complex, unfamiliar, or insoluble ambiguity)

[17] Despite Norton's use of the "ambiguity tolerance" label, Kajs and McCollum (2010) refer to this as a scale for "tolerance for ambiguity"
[18] Geller, while building on Budner and Norton, switches to use the label "tolerance *for* ambiguity"
[19] Despite McLain's use of the "ambiguity tolerance" label, Kajs and McCollum (2010) refer to this test as the Multiple Stimulus Types *Tolerance for* Ambiguity Test

- *Attitudinal Ambiguity Tolerance (AAT) Scale (Durrheim & Foster, 1997)*
  - Unlike most other measures, this scale is specifically designed to measure the content specificity of TA towards: religious authorities, conservative political authorities, political authorities, and familial authorities
- *Multiple Stimulus Types Ambiguity Tolerance scale-II (MSTAT-II) (McLain, 2009)*
  - Used by: Hazen et al. (2012)
  - Designed by McLain as a improvement over his MSTAT-I scale (1993), and to combat problems with existing measures of TA that "lack the content and structure needed for the theories they test" (p. 976)
- *Intolerance of Ambiguity scale (Naemi, Beal & Payne, 2009)*
  - Designed to predict extreme response style
  - Contains items from Rydell and Rosen, Budner, and Norton
- *The Tolerance for Ambiguity Scale (Herman et al, 2010)*
  - Used by: Dewaele and Wei (2012)
  - Developed for cross-cultural contexts.

A qualitative across-scale comparison reveals contrasting content, criterion, and construct validity.[20] For the scales to converge on content validity, we would expect each scale to operationalize the domain of TA in a consistent manner. They do not. Different scales employ different behavioural elements to represent TA. One example is the irregular use of rigidity as a characterization of TA: do researchers agree with Frenkel-Brunswik that rigidity and TA are synonymous, or with Budner, who differentiates rigidity from TA based on the former's relationship to stubbornness and the latter's

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[20] "Content validity": the instrument covers a representative sample of relevant behaviours. "Criterion-related validity": the instrument represents current behaviours (or predicts future outcomes). "Construct validity": the instrument measures what it is designed to measure. (Creswell, 2008, p. 172)

relationship to evaluation? For the scales to converge on criterion validity, we would expect the measures to correlate with one another as well as with other well-established measures. They do not. Researchers who create these scales choose different comparisons, and numerous critics indicate numerous problems with comparative correlations. Finally, for the scales to converge on construct validity, we would expect overall agreement on characterizations of TA, including its significance. This is not the case; various characterizations contain meaningful idiosyncrasies, including disagreements on situational and content dependence.

Do these problems imply that the TA construct should be discarded? Or does this mean, as implied long ago, that TA "may, rather, be less general or broad in scope than had been initially assumed" (Kenny & Ginsberg, 1958, p. 304). Perhaps the construct defies consensual definition as a measurable personality trait because TA does not exist as a unified and fixed concept. Its controversial factor structure might be elusive not only with regard to individual differences to different types of content, but also confounded due to individual and situational differences in agency and motivation. To push the point even further, perhaps the differences in construction of the TA concept and measurements relate to the different values of different researchers. Nevertheless, while "the definitive aetiology and correlates of AT [ambiguity tolerance] have never been made clear … this has not detracted researchers in the area" (Furnham & Ribchester, 1995, p.181).

***Contemporary applications (2000 - present).***

In this section, I examine recent peer-reviewed journal articles related to TA. I am less interested in the results of these studies, and more interested in questions, hypotheses, and implications for further research. My goal is to understand how contemporary researchers attempt to use this construct and why researchers continue to invest in TA research despite its problematic construction and measurement.

This review illustrates a continued emphasis on TA as a trait (sometimes general, sometimes situation-specific). The majority of contemporary researchers, especially outside of the field of education, continue to refer to TA as a predictive variable. For them, TA is measured and then used as an independent variable in relation to dependent variables such as: choice in profession, success in language learning, or propensities toward risk. However, a unique contingent of researchers also emerges from this review:

A subset of contemporary researchers avoids characterizing TA as an immutable variable. Instead, these researchers examine TA as a potentially malleable cognitive process. In this sense, TA is conceived of as a dependent variable that is itself an outcome, subject to change through intervention. In the following lists of research articles, I have marked with an asterisk (*) those cases where TA is theorized as a mutable variable (one that can change). It is interesting to note that the majority of research related to changing levels of TA is pursued in the field of education. Perhaps this is not surprising: educational goals include cognitive change toward self-regulation and a desire to instil in learners increasingly accurate pictures of reality.

Here are some examples of contemporary TA research, in the field of education:

- * Banning (2003) recognizes a paucity of research concerning the effects of educational interventions on levels of TA. He examines the effect of the “case method” on management students’ abilities to navigate the “complex nature of business decision making" (p. 557). In the case method, students read, analyze, and discuss written versions of real events, inherently full of ambiguous cues.

- * DeRoma et al. (2003) hypothesize that TA scores predict need for course structure as well as anxiety related to lack of course structure. Given that ambiguity and uncertainty are inevitable in both classroom and workplace, these researchers conclude with the suggestion that "instructors may also need to consider shaping higher tolerance levels [in students]" (p. 107).
- * Merenluoto and Lehtinen (2004) propose a model in which learning is moderated by TA, contingent on prior knowledge and motivation. They conceive of TA not as a stable trait, but as a metacognitive skill. They claim that TA reflects a learned ability to face the cognitive conflict that is required in order for radical conceptual change that is required to learn mathematical concepts. I will revisit this case to provide more detail, in my summary of the theorization of TA as a skill, below. Theirs is the most explicit contemporary characterization of TA that I have found.
- * Levitt and Jacques (2005) ask how TA might be "fostered among counselors-in-training to help them better grasp their roles and functions in a profession that is filled with ambiguous concepts (e.g., genuineness, empathy, active listening)?" (p. 49).
- * Kajs and McCollum (2010) investigate how TA affects leadership style and decision-making in the context of school principals, administrators, and professors. They suggest that TA might decrease with age, leading older administrators to be less willing to accommodate newer ideas.
- * Wayne et al. (2011) found that medical students with high tolerance of ambiguity scores were less likely to show declines in their attitudes toward client populations

that require complex treatments. These researchers acknowledge debate over "whether tolerance of ambiguity is a fixed or modifiable trait" (p. 880). They suggest that, "although we cannot change the fact that doctors face ambiguity in their work, we may be able to better prepare students to understand and cope with this ambiguity", for example, by paying attention to and providing practice with ambiguous situations during medical training (p. 881).

- Bakalis and Joiner (2004) hypothesize TA as a predictor for enrolment in student foreign exchange programs; they suggest that higher TA indicates propensities for challenge and risk.
- Bardi et al. (2009) expect TA to predict well-being only at the start of university studies because challenge and threat appraisals should diminish as students become accustomed to university life. Their findings emphasize the function of TA as situation-specific.
- Atef-Vahid et al. (2011) hypothesize that TA scores serve as a predictor in language learners' performance on a cloze test (a test for semantic comprehension), with more TA leading to better scores
- Dewaele and Wei (2012) hypothesize that TA correlates to multilingualism and to advanced proficiency in learning multiple languages. They also investigate the effect of growing up in a bilingual or multilingual household on TA, as well as the effect of living abroad on TA.

Here are some examples of contemporary TA research in fields not directly related to education:

- * Våpenstad (2010) suggests that TA is central to psychoanalysis, and he provides a case study in which a patient's TA is improved through the therapy process
- Chen and Hooijberg (2000) examine TA "on attitudes toward corporate interventions of valuing-diversity programs" (p. 2392); they suggest that low TA might inhibit managers from embracing diversity in the workplace
- Yurtsever (2000) hypothesizes a positive correlation between a manager's TA and his ethical relativism, and a negative correlation between TA and idealism
- Lane and Klenke (2004) suggest that, when navigating through ambiguous and uncertain situations, an effective leader first recognizes that she needs to learn something new. TA is proposed as a trait variable that moderates between goal-setting and effective leadership, and between self-efficacy beliefs and effective leadership.
- Hartmann (2005) hypothesizes that TA predicts the effect sizes of task uncertainty and of environmental uncertainty on managers' opinions about the appropriateness of measuring performance through finances. TA enables management of uncertainty.
- Hunter (2006) hypothesizes that "in the face of an organizational threat/risk, there is a positive relationship between tolerance for ambiguity and the perception of an opportunity to overcome adversity", "a positive correlation among individuals who score high on tolerance for ambiguity and charismatic leadership," and "a positive correlation among individuals who score high on the Big Five Personality factors and tolerance for ambiguity" (p. 49)

- Quillin et al. (2008) hypothesize “that educational background will predict [patients’] awareness of genetic testing more strongly among individuals with higher TFA [tolerance for ambiguity]” (p. 1228)
- Zenasni et al. (2008) “hypothesized that the more individuals (children and adults) are tolerant of ambiguity, the greater their creative potential and the more they will show creative productions” (p. 63). They also investigate the hereditable links between creativity and TA.
- Endres et al. (2009) hypothesize that, in complex organizational decisions (but not in simple decisions), TA moderates between task complexity and self-efficacy, and between task complexity and accuracy of predictions of self-efficacy
- Naemi et al. (2009) hypothesize TA as a predictor for extreme response styles; individuals with lower TA are thought to exhibit a “tendency to disproportionately favor the endpoints or extreme categories of ordinal response or Likert-type scales” (p. 261)
- Trottier et al. (2012) suggest that TA might predict parents’ willingness to participate in potentially uncertain research, specifically genetic research in autism
- Hazen et al. (2012) hypothesizes that TA predicts consumer willingness to purchase remanufactured products; they suggests that managers should reduce the level of ambiguity associated with remanufactured products in order to increase sales
- Zhu et al. (2012) question the predictive interaction between TA and message source (word-of-mouth versus official publicity) on risk perception and the purchase of insurance related to earthquakes; they suggest that individuals with higher TA are more aware of risk, and less likely to be mislead by rumour.

This review of contemporary research reveals TA as a theoretical mediator in a variety of behavioural choices. In decisions related to medicine, marketing, management, and education, lack of TA is viewed as a problem. This review also reveals that, in the field of education, researchers are less committed to the theory of TA as an immutable personality trait. Researchers in education recognize the moderating quality of TA; yet they also recognize that this moderator is not necessarily fixed. Researchers in the domain of education appear more likely to investigate the possibility of maximizing students' TA, in preparation for inevitable, real-world ambiguities.

**Theories of tolerance of ambiguity.**

Definitions of TA are diverse and lack unanimity (Bors et al., 2010; Rydell & Rosen, 1966). To some researchers, the TA construct is "almost self-explanatory" (Eysenck, 1954, p. 221). To others, the construct has been over-extended (Grenier et al. 2005; Kirton, 1981) and claims of its measurement are inconclusive (Bors et al., 2010; Furnham, 1994; Tsui, 1993). While the concept continues to drive a wide variety of research questions, inconsistency in its characterizations provides ground for reflection. What is TA? Two distinct interpretations are apparent: TA as a trait (either in general or in relation to specific situations or content types) and TA as a metacognitive skill (not merely a trait). I have already described these theories to some extent, in previous sub-sections. Here, I provide more detail, especially in regard to the theory of TA-as-a-skill, because this interpretation appears less often in historical literature. I also summarize evidence of researchers' support for each theory, which illustrates the ambiguous nature of the TA construct.

***TA as a trait.***

"A trait is a dimension of personality used to categorize people according to the degree to which they manifest a particular characteristic" (Burger, 2000, p. 172). While traits may vary across situations, on average, traits are assumed to be stable over time.

TA was first hypothesized as a trait by Frenkel-Brunswik (1949). Although she explicitly questioned how well it would generalize (Frenkel-Brunswik, 1949, p. 112), her research became integrated into a highly politicized and complicated theory: authoritarian personality theory. Adorno's theory is difficult to grasp, yet its goal – to identify threatening personality types – remains alluring. I believe the superficial popularity of that theory contributed to a premature legitimization of the TA-as-a-trait construct. According to Kenny and Ginsberg (1958):

> Much of the research stimulated by The Authoritarian Personality tacitly assumes that intolerance of ambiguity is a generalized trait. At the present time, however, the basic data to substantiate or vitiate such an assumption are surprisingly not available, in spite of the plethora of measures purporting to measure intolerance of ambiguity and the fact that Frenkel-Brunswik expressed caution about assuming the generality of the construct when she initially introduced it. (p. 300)

Budner (1962) provides the most common trait characterization of TA: "the tendency to perceive (i.e. interpret) ambiguous situations as sources of threat" (p. 29). Budner acknowledges the complexity of personality in his discussion about the indeterminateness of personality traits. While he admits that TA "plausibly" fits within an individual's hierarchy of values, he primarily suggests that TA is a trait that is used for evaluating but not handling reality. He writes that TA "cannot be considered a coping mechanism" and he balks at characterizing TA as "a lever for manipulating the environment" (p. 48). Many researchers have built and continue to build upon Budner's conception.

The follow researchers persist in assuming TA is a trait, either generally or specifically in relation to situations:

- MacDonald (1970) acknowledges that "definitions overlap considerably, no common definition has been accepted" (p. 791) yet he agrees with Budner that TA is a "general tendency" (p. 791) and he treats it as a trait
- Norton (1975) refers to TA as a "trait that touches many behavioural phenomena", for example: reluctance to "think in terms of probabilities" and preference to "escape into whatever seems concrete" (p. 607). While Norton proposes several research avenues for more precise accounts of TA, he does not question its mutability as a trait.
- Sidanius (1978) refers to TA as a "generalized trait of personality" (p. 215)
- Rotter and O'Connell (1982) refer to TA as a trait (p. 1218)
- Ray (1987) suggests that "Rather than being consistent personality traits across measures and across situations, cognitive styles such as rigidity and intolerance of ambiguity seem to be measure specific and situation specific" (p. 560). This theorization provides good insight, yet falls short of a phenomenological perspective.
- Likewise, Ely (1989) wonders "whether to consider personality or cognitive style variables as being relatively stable or as varying according to the situation" (p. 437)
- Anderson and Schwartz (1992) see TA as a trait that predicts depression "in the presence, but not in the absence, of rumination about negative life events" (p. 277), a situation-specific trait interpretation
- McLain (1993) identifies three perspectives on TA, all of which assume it is a trait: (1) perceiving novel, complex, and/or insoluble ambiguities as sources of threat, per Budner; (2) associating TA with authoritarianism and prejudice, per Frenkel-

Brunswik; (3) judging future probabilities under uncertain conditions in a predictable attitudinal manner, per Ellsberg (this construction conflates TA with the "ambiguity aversion" construct) (p. 184).

- Chen and Hooijberg (2000) write that "ambiguity intolerance is a well-established personality variable" (p. 2394)
- Sallot and Lyon (2003) refer to Frenkel-Brunswik's and Budner's conceptualizations of TA as a personality trait "that should remain fairly stable over time" (p. 254)
- Bakalis and Joiner (2004) lump TA into a list of "consistent characteristics (or traits) within an individual that affect the way they interact with others and the situations they encounter" (p. 287)
- Hartmann (2005) treats TA as an individual characteristic (p. 245)
- Clampitt and Williams (2007) refer to TA within the realm of "personality traits" (p. 315)
- Zenasni et al. (2008) write that "tolerance/intolerance of ambiguity is generally considered to be a personality trait" (p. 62)
- Naemi et al. (2009) refer to TA as a "stable personality trait" (p. 262)
- Herman et al. (2010) suggest that TA is an individual tendency that is affected by context (p. 59)
- Litman (2010) treats TA as an attitudinal disposition (p. 399)
- Trottier et al. (2010) treat TA as "a general personality trait" (p. 3)
- Hazen et al. (2012) treat TA as a personality trait (p. 782)
- Zhu et al. (2012) treat TA as a personality trait (p. 3).

As a trait, TA resembles a reified, innate essence. It is assumed to be stable over time: a behavioural disposition that does not evolve, despite new experience or subjective agency. However, grounds for this interpretation are weak. In spite of more than a half century of research, little evidence exists to show stability of this trait over time. Furthermore, this treatment belies a psychological limit, which, if perpetuated, systematically biases individuals to not progress beyond the perceived limit. In effect, belief in general trait theory can be self-perpetuating. Situational affordances and agency are deemphasized or ignored; development is undermined.

Some researchers are sceptical of assumptions regarding the general stability of TA. Kenny and Ginsberg (1958) write: “It would be unwarranted to infer that a person who is intolerant in one situation will be intolerant in all equivocal situations” (p. 304). Referring to Budner’s definition, Rydell and Rosen (1966) write: “It is difficult to identify an ambiguous situation; the defining stimulus variables can be sampled from diverse domains such as in perceptual experiments, projective tests, and social situations” (p. 149). Durrheim and Foster (1997) emphasize “little empirical basis for assuming intolerance of ambiguity to be a stable and generalized personality trait”; they stress that their scale “does not measure a reified internal cognitive trait” (p. 742).

To extend the theorization of TA into situations (i.e., an environmental perspective) is necessary yet still insufficient. In this extended theorization, behaviour is explained through two perspectives: by internal (genetic) factors and by external (situational or contextual factors). The dominant discourse in these theorizations idealizes fixed knowledge and certainty in causal explanations: behaviour is produced by innate trait or by external circumstance. Such researchers still fail to broach the subject of metacognition or motivation. These researchers neglect the experiential bridge between trait and circumstance. They overlook subjective awareness of this bridge, and its systemic effects on future experiences. In short, they ignore the phenomenological perspective, which obscures possibilities for development of TA.

***TA as a skill.***

Beyond a trait, TA can be conceived as a skill. Merenluoto and Lehtinen (2004, p. 255) provide an apt summary of this approach:

> Originally the tolerance of ambiguity was understood as a personality variable, but here we consider it to be a more specific variable referring also to the domain of the needed change. It can further be explained as a dynamic process of metacognitive and motivational variables. Thus, coping with a new complex conceptual system is possible only if the learner has sufficient metacognitive skills to grasp conflicting notions. This is, however, not enough, but he or she also needs to be motivated to deal with the ambiguity, and to trust that the experienced conflicts are solvable.

These researchers consider TA as part of the process of metacognition that enables conceptual change. Their theoretical process suggests that, given sufficient prior knowledge, motivation, and trust, a learner can: experience conflict, reduce certainty in existing knowledge, and construct new knowledge. This characterization of TA engages with all three of Mischel's perspectives: as a theoretical construct that mediates behaviour; with a focus on domain-specific dissonance that elicits behaviour; and, most dynamically, in terms of phenomenological motivation and experience. In this regard, TA ceases to appear fixed and reified. Instead it is agentive and active. With appropriate internal and external support, TA can be developed.

In addition to Merenluoto and Lehtinen, a number of other researchers reinterpret TA beyond trait conceptions. Not all of these researchers identify TA as a metacognitive process as do Merenluoto and Lehtinen. Nevertheless, the following researchers validate further research against trait stability:

- Furnham and Ribchester (1995) describe clinical disillusionment over the fact that TA has been conceived "as a stable independent variable rather than a flexible dependent variable" (p.185)
- Banning (2003) disputes "previous work involving TA [that] treats ambiguity tolerance as a fixed quality of an individual" (p. 566)
- DeRoma et al. (2003) encourage development of TA due to the inevitability of ambiguity in classrooms and workplaces
- Våpenstad (2010) suggests that TA can be improved through successful psychotherapy
- Kajs and McCollum (2010) recognize TA as "intricate and complex" (p.78) and their research suggests that, for educational administrators (e.g., principals), TA decreases with age.

According to Kajs and McCollum (2010), hypothetical factors that might contribute to the decline of TA over time include: habituation to ambiguity from experience ("with age, fewer incidents appear ambiguous, possibly due to having dealt with more situations", p. 85); increased avoidance of cognitive dissonance ("older educators may be more inclined to avoid (be cautious in) obtaining new or updated information", p. 86); increasing conservatism aimed at prevention of uncertainties (e.g., "wanting to ensure stability" related to social standing, financial security, etc., p. 87). These explanations invoke subjective experiences as motivators for TA. However, Kajs and McCollum do not explicitly ask if these individuals are aware of these changes, or if individuals can drive these changes. Yet, in the domain of education, this is the most relevant question: how might we become conscious agents of cognitive change?

The following researchers suggest means for improving TA:

- DeRoma et al. (2003) suggest that instructors and students should collaborate and communicate on the subject of ambiguity tolerance to reveal inherent stresses and discomforts with unstructured aspects of coursework and evaluations. “If students can be introduced to and accept the notion that a flexible approach to structure is optimal, they may be more motivated to perform in a setting characterized by varying levels of classroom structure” (p. 108).
- Banning (2003) suggests that “case teaching may increase TA in students by providing guided practice in decoding ambiguous cues that are embedded in the social and decision contexts of the case narrative” (p. 558)
- Levitt and Jacques (2005) encourage in student counsellors: reflexive thinking, active listening, semi-structured experiences, relinquishment of perfectionism, and “grappling with the unknown” (p. 50). To increase TA in students, they encourage instructors to: rely on practice over exposure; “embrace the trial-and-error approach to skill acquisition”, and encourage reflexivity through peer reviews and group supervision (p. 52).
- Wayne et al. (2011) suggest that medical school instructors may be able increase students’ TA by “directly acknowledging the ambiguity inherent in medicine and the anxiety that it can cause. We need to kindly remind our students of their human nature and thus their fallibility” (p. 881).

- Dewaele and Wei (2012) suggest that experience in "a foreign environment forces people to become more attuned to differences and brings with it an awareness that their own values, beliefs and communicative practices are not necessarily shared," which potentially increases TA (p. 8)
- Merenluoto and Lehtinen (2004) urge the use of "teaching methods that support the development of meta-conceptual awareness and the use of metacognitive strategies in dealing with conflicting notions" (p. 531).

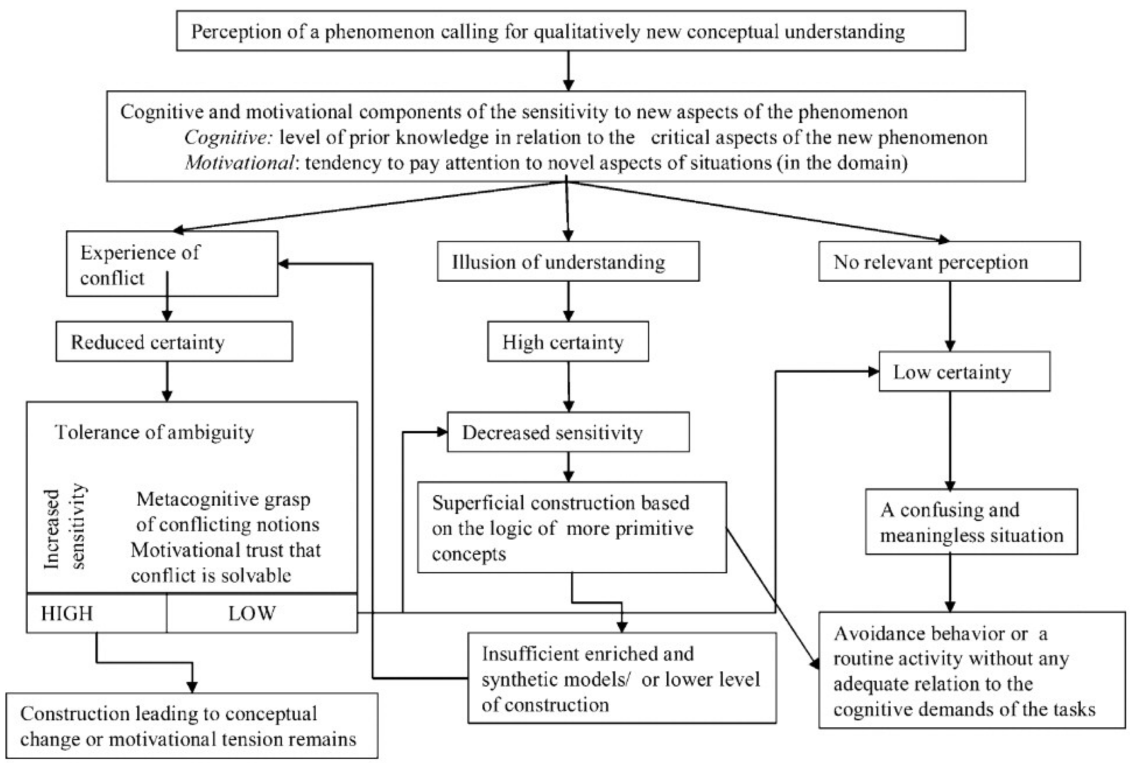


*Figure 4.* Merenluoto & Lehtinen's (2004) theoretical model for conceptual change. Adapted from "Number concept and conceptual change: Towards a systemic model of the processes of change," by K. Merenluoto and E. Lehtinen, 2004, *Learning and Instruction, 14*, p.524. Copyright by Elsevier B.V.

Merenluoto and Lehtinen (2004) provide a detailed investigation of TA as a process. They identify three possible paths during learning, one of which leads to radical conceptual change: the experience-of-conflict path (see Figure 4). In this path, conceptual change depends on: prior knowledge, sensitivity to novel features of a situation, an experience of conflict between prior knowledge and novel features, and trust in the process of tolerating the ambiguity produced through the conflict. This implies that an experience of conflict is necessary but not sufficient to invoke conceptual change. Individuals must be motivated to trust and tolerate the uncertainty of the conflict. According to this model, TA is interpreted within a larger metacognitive system. Conceptual change depends on motivational, cognitive, and metacognitive processes, including a learner's increasing sensitivity to ambiguity.

As an example of the TA process, Merenluoto and Lehtinen (2004) investigated the radical conceptual change required to progress from natural numbers (like 1, 2, and 3) to rational numbers (ratios like 3/4 or 7/3). Some of the rules that characterize natural numbers are incompatible with rules that characterize rational numbers; for example, rational numbers are dense (there are no gaps in this number line). To grasp rational numbers, learners must accommodate a novel interpretation of the "number" concept. Merenluoto and Lehtinen tested 538 Finnish upper secondary school students. They measured three outcomes with respect to classifying and constructing natural and rational numbers: success in answers, over-confidence in answers, and avoidance (lack of answers). Their data revealed three profiles (corresponding to the three vertical paths in Figure 4): no relevant perception (i.e., avoidance without over-confidence; the right-most path); illusion of understanding (some avoidance and some over-confidence; the middle path); and an experience-of-conflict path (no over-confidence, no avoidance; the left-most path). Qualitative analysis revealed that students in the experience-of-conflict profile gave explanations that reveal metacognitive comfort with conflicting notions:

"they consistently identified the abstraction of limit in explaining the density of numbers, like 'it is not possible to define the next one, because the principle of the next number is valid only in the domain of natural numbers or integers'" (p. 528)

A learner can progress from natural numbers to rational numbers only by accommodating a radically different number theory. Merenluoto and Lehtinen (2004) acknowledge that catching students in the act of radical conceptual change is not easy: "Because conceptual change is a slow process, observing a construction or observing the increasing or the decreasing sensitivity might be problematic" (p. 532). However, in a related study, Merenluoto and Lehtinen used a "think out loud" protocol to capture the thoughts of six students who were struggling with rational numbers. They witnessed one student in the midst of the experience-of-conflict path. Ann already has some intuition of the difficult problem. Then, "increased sensitivity leads her to express a profound and correct realization: 'you can always divide it into smaller and smaller parts'"; however, her tolerance is not yet sufficient, she subsequently "gives up and returns to her prior familiar explanation" (p. 531). Merenluoto and Lehtinen suggest that, with sufficient time, motivation, and trust, "the learner does not base his or her thinking merely on established knowledge but is prepared to change his or her knowledge beliefs" (p. 525).

***Conclusion – Toward a Theory of Tolerance of Ambiguity***

My historical exploration of TA provides background into its genesis. To summarize: early research revealed individual differences in response to ambiguous perceptual stimuli. Psychoanalytic theories motivated the search for personality factors related to maladaptive perception. Frenkel-Brunswik hypothesized a TA personality type and she offered a series of experiments to objectively measure individual differences.

These experiments bore little fruit, yet the construct was prematurely adopted in part due to a timely political project: researchers appeared desperate to understand rigid thinking and submission to authority in light of the horrors of WWII. Adorno suggests that complex phenomena (including complex social structures) evoke “excessively rationality”: short-sighted certainty in lieu of costly critical analysis. Critics remark that authoritarian theory itself can be misinterpreted as an excessive quest for certainty. In both accounts (Adorno’s and those of his critics), we are warned not to be fooled by apparent authority.

Budner and many subsequent researchers highlight the complex nature of personality. Nevertheless, these complexities are routinely simplified into pencil-and-paper measures that attempt to circumscribe TA as a fixed or situation-specific personality trait. Hundreds of studies refer to the concept, which testifies to research interests related to TA; however, results appear inconclusive. Meanwhile, over time, the field of psychology is changing. Advances in neuroimaging techniques are validating theories related to brain plasticity, which challenges theories of trait stability. The search for either internal or external causes for behaviour is being replaced by a more dynamic picture that accommodates internal and external causes in concert, with increasing emphasis on motivation and longitudinal change. In the domain of education, under constructivist theories: emphasis is increasingly placed on the learner as an active agent who transforms reality.

The TA concept finds new meaning when described as “a dynamic process of metacognitive and motivational variables” (Merenluoto & Lehtinen, 2004, p. 525). As part of a larger metacognitive system, TA is understood to play an integral role in conceptual change, including the relinquishment of existing beliefs. Merenluoto and Lehtinen (2004) paint a complex and dynamic picture of learning. Like Dewey and Vygotsky before them, they invoke cognitive conflict as a necessary precursor to development. They further describe the required motivational and metacognitive variables. Specifically, in order to manage cognitive conflict, one requires motivation and trust to endure the slow sensitization to novel aspects of a phenomenon, which eventually leads to a series of "aha" moments in which prior knowledge yields to richer conceptions.

I advocate for Merenluoto and Lehtinen's theory. As a cognitive process that can be acknowledged, modelled, and nurtured, TA remains appealing for three reasons: it helps to explain the continued interest in the predictive power of TA in models related to conceptual change; it converges with contemporary personality research that normalizes complexity and change over time; it sidesteps issues related to the problematic construction of a stable trait. My recursive application of the process of TA onto the concept of TA provides a case in point. Through motivation to overcome the cognitive dissonance that I encountered while researching this construct, I have detected novel features of the TA phenomenon. Rather than retain the dominant interpretation of TA as a stable trait, I have reconceptualised TA as a dynamic process for conceptual change. Because conceptual change forms the basis of education, TA should be of interest to pedagogues.

In their review of the emerging field of research in "psychological wisdom", Staudinger and Gluck (2011) write:

> The main issue in postformal [Piagetian] cognition is the realization that universal truths, as required for formal logic, can seldom be identified in the more complex problems that humans face. Such problems (e.g., interpersonal conflicts) are often characterized by the presence of multiple truths, incompatible goals,

> contradictions, and high levels of uncertainty. Thus, tolerance of ambiguity and willingness to compromise are more useful than strict formal-logical decision-making. (p. 224)

Staudinger and Gluck recognize TA as an "availability of strategies to manage this uncertainty through openness to experience, basic trust, and the development of flexible solutions" (p. 229). When conceived this way, TA escapes the potential rigidity that accompanies the ontological "what" question, which assumes that TA can be fixed and formally defined as if it refers to some objective "thing" (viz. representational theories of mind). This alternate conception allows practitioners to concentrate instead on the practical "how" question, which depends less on a formal definition, and more on an instrumental/operational understanding of an experiential process by which concepts are acquired.

In conclusion, TA refers to increasing sensitivity to novel features of a phenomenon toward radical redefinition of prior conceptual interpretations. TA depends on a learner's trust and receptivity to cognitive dissonance in relation to prior knowledge. As such, TA reflects a metacognitive skill more than a stable trait. By modelling the operational power of TA in conceptual change, theorists, educators, and learners turn their attention to the cultivation of new knowledge. We must recognize that knowledge is bound to experience. Knowledge expands not through an achievement of certitude, but through a motivated quest for ongoing growth and progressive understanding.

In the following section, I argue that, similar to TA, educational technology benefits when attention is drawn away from the "things" of technology, and drawn toward the "processes" of technology. The instrumental use of educational technology, including the processes of educational technology, is more important than its precise definition and more important than a taxonomic inventory of the current marketplace for hardware. Definitions and wares are likely to evolve. Meanwhile, the ability to cultivate new concepts is itself a valuable technology. And it is precisely through its use that technology can be understood.

## What is Educational Technology?

Educational Technology (ET) refers to the use of technology in the process of education. But what is technology? And what is education? In the sub-sections, below, I will address these questions before reaching the focus question, what is ET.

In brief, various interpretations of ET exist. Most readily, ET is interpreted with regard to “hard technology”. Hard technology refers to human-made material resources such as computer hardware and software. This interpretation dominates popular and political discourse. For example, literature published by the U.S. government’s Office of Educational Technology refers exclusively to hard conceptions of technology. However, less intuitively, ET can be interpreted also with regard to “soft technology”. Soft technology refers to human-made (immaterial) processes, including styles of thinking, methods of organization, theories, and culture. Soft, “process” conceptions of technology are further subject to numerous interpretations. The Association for Educational Communications and Technology (AECT) suggests that TA processes must be “intellectual”. However, I suggest that non-intellectual processes (such as biological processes) can be intellectualized (grasped mentally) and can affect the intellect in perceptible ways. Therefore, such “non-intellectual” processes might also be exploited in ET design. Ultimately, I advocate for sensitivity to broad interpretations of processes that can be used in the design of learning systems. Appreciating various interpretations of technology potentially invigorates the ET concept, dispels myths that limit ET to hardware requisition, challenges views related to pre-authenticated knowledge, and leads to the ongoing evolution of future technologies, including future processes and hardware.

To frame my broad interpretation of the ambiguity of process conceptions of ET, I begin this section with two preliminary questions– what is education, what is technology. The first sub-section contains a description of Dewey's theory of education-as-growth, which is a learner-centered approach that emphasizes interactive experiences and social consequences. The second sub-section describes three diverse philosophical interpretations of technology. I chose these interpretations because they illustrate important yet unintuitive process conceptions of technology. Technology can be interpreted as a cognitive process that shapes and is shaped by experience. Technology can be seen as a symbiotic biological agent. And technology can be understood as a cultural force. Understanding each of these conceptions enlivens the ET practice. Finally, in the third sub-section, I take up an examination of the ET construct itself. This includes a review of the history of ET and its definitions, and analysis of interpretations of ET in relation both to hard technology and to soft technology.

My goal in this section is to critically evaluate theories of ET in order to identify gaps and to propose a solution. The main fallacies that I identify with respect to ET are: (a) limited interpretations that restrict ET to hard technology and (b) a misconception that processes must begin with pre-authenticated scientific knowledge, which neglects experiences that give rise to knowledge in the first place. I address these shortcomings by proposing TA as a solution.

### *Education as Growth*

According to Dewey, education interactively supplies the means for and creates the desire for continued growth through experience. Growth is an organic process of living characterized by active adaptation to new or changing conditions. Unlike *habituation*, which refers to persistent and stubborn responses, *habitual adaptation* refers to the plasticity of an organism, “the power to learn from experience” (Dewey, 1944, p. 52).[21] For example, “for the child to realize his own impulse by recognizing the facts, materials, and conditions involved, and then to regulate his impulse through that recognition, is educative” (Dewey, 1990, p. 40). Effectively, Dewey distinguishes between “learned behaviour” and “behaviour that results in learning”. On the one hand, learned behaviour can be thought of as a toolbox – an apparently dependable repertoire of knowledge that an organism uses. On the other hand, education must encourage ongoing growth of the toolbox, the production of new tools. Learning, as an outcome of controlled thinking, reflects an ongoing revision of knowledge. In effect, active inquiry serves to ameliorate insufficient knowledge.

Dewey emphasized inquiry and growth because “the future is always unpredictable” (1999, p. 82). His belief in the iterative development of knowledge can be contrasted with a quest for certainty (for example, the pathological “excessive rationality” as described by Adorno), which prizes final outcomes above all. Dewey encourages habitual learning with no resolute end other than learning itself.[22] A school education is valuable insofar as it instils “a desire for continued growth and supplies means for

[21] “Habits take the form of both habituation, or a general and persistent balance of organic activities with the surroundings, and of active capacities to readjust activity to meet new conditions. The former furnishes the background of growth; the latter constitutes growing.” (Dewey, 1944, p. 52).
[22] “Since growth is the characteristic of life, education is all one with growing; it has no end beyond itself” (Dewey, 1944, p. 53).

making the desire effective" (Dewey, 1944, p. 53). In other words, education cultivates continuous development of knowledge and habitual adaptation. Education is not about conveying a fixed set of ideas, recipes or tools. While ideas, recipes, and tools do serve a purpose (as warranted by situations), Dewey's instrumental philosophy emphasizes acquisition above ideas themselves. Rather than reify ideas (i.e. to dislocate them from practice), Dewey encourages the exploitation of ideas as instruments of discovery both for individuals and for society at large. Ideas function as malleable tools of inquiry for the ongoing development of democratic ideals, as required in a shared and ever-evolving world. In effect, knowledge is practically organized for the liberation of human intelligence. Inquiry is designed to challenge intellectual and cultural limits, ad infinitum.

A necessary consequence of Dewey's philosophy of education is a relinquishment of certainty. According to Larry Hickman (1990), Dewey "admitted that his work constituted an open rebellion against the long philosophical and religious tradition that identifies knowledge with final certainty" (p. 37). In Dewey's perspective, knowledge ceases to be fixed and immutable. The plasticity of knowledge is self-evident because knowledge is inextricably entangled with organic experience. Truth gives way to warranted assertion, which arrives only via situated experiments in reality.

### *Three Philosophical Conceptions of Technology*

In their 2008 definition of the ET concept and field, the AECT includes both hard technology and soft technology. By soft technology, the AECT specifically means "intellectual processes" – transformative methods or actions that facilitate learning and performance (Januszewski & Molenda, 2008, p. 196). As an intellectual process, technology is thought to mediate between inputs and outputs (see Figure 5. The AECT's

Input – Process – Output paradigm). By concentrating on “human made processes that systematically apply scientific knowledge”, the AECT intentionally neglects “nontechnical processes, such as cognitive processes, biological processes, and spiritual processes” (Januszewski & Molenda, 2008, p. 197).

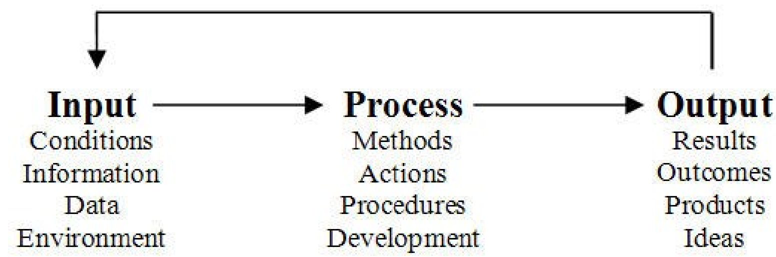


*Figure 5.* The AECT’s Input – Process – Output paradigm. Adapted from *Educational Technology: A Definition With Commentary* by A. Januszewski and M. Molenda, 2008, p. 196. Copyright 2008 by Routeledge.

The AECT’s demarcation between “technical” and “nontechnical” processes is interesting. It attempts to delineate which processes belong in the field of ET and which do not. However, this demarcation appears subjective; it can be interpreted as an arbitrary distinction if one acknowledges that technological processes affect and are affected by cognitive, biological, even spiritual processes: while science and the intellect affect technology, technology also affects science and the intellect. The boundary between processes that are human-made and those that are not is ambiguous – open to more than one interpretation. The proposition that the intellect must inform technology, and that cognitive, biological, and spiritual processes are non-technical, presupposes the existence of an intellect. One might ask: Where does the intellect come from? Some philosophers suggest that not only does the intellect give rise to technology but that technology also gives rise to the intellect.

In the following paragraphs, I present three philosophers' theories of technology. These theories challenge the AECT demarcation of "technical" versus "nontechnical" processes. While each of these philosophers has (necessarily) "intellectualized" the process that he writes about (i.e., in order to write about it, he has attempted to transcribe it), the technological processes themselves arguably exist in a realm beyond the intellect. For Dewey, technology includes inquiry, a process that habituates intellectual adaptation through interactive experience. In this view, prioritizing intellect ahead of cognition is illusory: knowledge itself is understood as a technological artefact. For Don Ihde, technology is not neutral or "out there". Biology and technology interface for intentional and symbiotic transformation. Finally, Harold Innis emphasizes the impalpable power of technology to shape culture over time. His analysis suggests that we can revitalize culture profoundly through a progressive understanding of technology as "cultural grammar". By providing these alternate interpretations, my goal in this sub-section is not only to elaborate on the ambiguity of technology, but more significantly to provide theoretical grounds for situating technology at multiple levels – experiential, biological, cultural – and to challenge the lopsided view that technology emerges from science.

**Dewey's conception of inquiry as technology**

Science is not ontologically superior to technology (Hickman, 2001, p. 10). Scientific knowledge itself can be understood as a technological artefact. In this interpretation, technology includes inquiry – a tool for regulating experience. Knowledge enters into and is refashioned through productive inquiry.

Unlike habit, whose blind allegiance to impulse rigidly assumes one situation to be essentially the same as the next, Dewey's principle of knowledge rests on the freedom of prior experience to be subject to, and informed by, new experience (Dewey, 1944, p. 340). Experience is educative to the extent that an individual can realize his impulses by recognizing the conditions involved, and then regulate those impulses through that recognition (Dewey, 1990, p. 40). For example, a mechanic who only understands a machine by virtue of habitual repairs will find himself lost when an unexpected situation arises; whereas a mechanic who understands the machine "knows the conditions under which a given habit works, and is in a position to introduce changes which will readapt it to new conditions" (Dewey, 1944, p. 340). This general pattern of productive inquiry – controlled thinking and regulated action, where theory and practice are equal partners – is "in its robust sense" a technology (Hickman, 2001, p. 181). According to Hickman (1990): "Controlled thinking is technological insofar as it utilizes tools and instruments: some of those tools are conceptual, some physical, some, the hardware that extends our limbs and senses" (p. 36). Dewey's technological inquiry implicates all of these tools, material and immaterial alike. To put it abstractly: the process of inquiry is a pragmatic technology, which itself utilizes and produces material and immaterial technological artefacts (including knowledge), and these artefacts themselves can be viewed as technologies (recursively emerging). In the example of the successful mechanic who can navigate novel problems, he utilizes technology (inquiry) to attend to technology (a machine). Critically, this general pattern applies to *all* types of inquiry, "cases that involve what we would call hardware, and it also fits cases that are patently conceptual … it applies to logical and mathematical proofs, and it applies in social and political inquiry" (Hickman, 2001, p. 33).

Throughout his work, Dewey stresses the interactive nature of experience. We bring ourselves and our faculties *into* experience. The implication is that knowledge must not be viewed as fixed, but must be viewed as continuously amenable to evolution in order for it to function in novel situations. In this regard, the tools that we use (including knowledge) “do not stand apart from a situation, but enter into it” (Hickman, 1990, p. 22). Dewey’s emphasis on the interactive nature of tools provides contrast against the limiting view of tools as separate and objective artefacts. Of course, tools can be considered artefacts, for example, when understood in the context of a museum. However, for tools to be considered active and educative, we must enliven them by involving them and reflecting on them experientially. Knowledge itself, including conceptual definitions, can be seen as a tool that comes alive through the process of inquiry. Furthermore, the process of inquiry can be understood as technological in that it utilizes and activates prior knowledge.

Knowledge clearly enters *into* the process of inquiry. Yet knowledge is also a *product* of inquiry – a technological artefact. In other words, knowledge is not just inputted into the process, but is also an output of the process. In Dewey’s conception, knowledge is constituted and refashioned through the process of experience. This implies that knowledge is not intrinsic; it is not discovered or unearthed; it is not a transcription of reality; it is not permanently abstracted ideas; it is not absolute or eternal. Instead, the process of inquiry iteratively refashions knowledge. Again, the process of inquiry is technological, with knowledge playing an active role. In this sense, knowledge is viewed not only as tool that enters into the technological process of inquiry, but knowledge is also seen to evolve as a result of inquiry. By placing knowledge in both positions, as input and as output, knowledge ceases to be stuck in the position of an *a priori* (before experience) object of reflection. Knowledge can be perceived also as a *posteriori* (after experience) result of reflection. Based on the latter appraisal, technology can be situated prior to science: the tool (inquiry) creates the knowledge, rather than knowledge creating the tool.

Dewey's instrumental theory is not particularly intuitive. He subverts some popular assumptions. He rejects the idea that knowledge corresponds directly with objects in the world. He questions the precedence of science to technology. Perhaps most critically, he favours continuity over discrete dualisms, deploring the false dichotomy of intellectualism versus emotion (see, for example, Dewey, 1944, p. 333). While acknowledging that abstract intellectualism promotes clarity, consistency, and much-needed relief from superstition, he also writes of its "formal and empty nature": "bare logic, however important in arranging and criticizing existing subject matter, cannot spin new subject matter out of itself" (Dewey, 1944, p. 299). Inquiry is deemed technological precisely when it regulates the ongoing *development* of knowledge.[23] This learning process, according to Dewey, is based in experience. To reduce the educative wealth of experience down to a formal process of applied intellect, as the AECT definition appears to propose, could promulgate an unfortunate illusion. Ambiguously, the intellect must also be viewed as the product of inquiry.

[23] "Technology was for Dewey an active method of generating and testing new skills, as well as reconstructing old ones" (Hickman, 1990, p. 19)

**Ihde's conception of intentional technology.**

Technology refers also to material culture, which Ihde considers an extension of our biological processes. Not only do we shape technology, but technology also shapes us, altering our perceptual capacity.

Like Dewey, Ihde subverts the popular assumptions that technology is separable from the individual and that it can be objectively intellectualized and permanently abstracted. Ihde (1990) writes that the dissociation of user from technology is a "persistent illusion" (p. 164). Humans have evolved to be intrinsically associated with technology. He refers to our material culture as "technology in the very broadest sense" (p. 13). We live in it: we create it and we are created by it. Because we simultaneously perceive material culture yet also shape material culture, the boundary between human subject and material technology is blurred. We cannot, for example, separate direct bodily perception from technologically mediated perception. As an example, consider a blind person's cane. Not only will a blind person know the shape of the world through the cane, but she may report feeling physically that the cane is part of herself. This anecdotal feeling is supported by mounting evidence that manipulable objects "external" to the body do, apparently, arise "internally" in the brain's body schema (see, for example, Carlson, Alvarez, Wu & Verstraten, 2010, and Maravita & Iriki, 2004). In other words, it seems that the brain literally incorporates the cane. According to Ihde (1990), it is not only canes and other props that serve as technology: "virtually all human activities implicate material culture" – and our technological infusion "forms the context for our larger perception" (p. 18).

Ihde describes technology as “intentional” yet “structurally ambiguous”. By intentional, Ihde means that technology delimits the context within which we perceive – it shapes our options. This does not imply that technology is deterministic (i.e., it does not totally control us). However, it does destabilize the assumption that technology is neutral (we do not totally control it). Ihde implies that technology persuades us to realize certain possibilities, and dissuades us from others. For example, by their shape, my eyeglasses mediate my sense of space as well as frame my vision, which lends direction to my focus, and which transforms my very being.[24] Ihde further emphasizes that our relations with technology are never fixed, they are always structurally ambiguous. By ambiguous, Ihde means that technology has a range of uses and interpretations depending on cultural context and physical limits. To assume our relationship with technology has a unitary purpose or unitary effect is misleading.

Ihde reformulates the question of “is technology good or bad” by “stressing that technology must always be placed within a cultural context and within an immediate bodily reaction simultaneously” (Connell, 1996, p. 10). In other words, our senses operate through material culture; simultaneously, because we contribute to its creation, our field of material culture is, in a real sense, constituted through our senses. This means that judging technology in a decontextualized manner is quite literally “nonsense”. Unfortunately, decontextualized judgements appear to be common and convenient, judging by the desire for universal prescriptions in medicine and education. While general prescriptions do serve a purpose, contextually cognizant scepticism can enable further insight, thus disabling premature and possibly debilitating reduction.

[24] Evidence of the effects of prescription glasses have been detected in the visual cortex (e.g., Press & Press, 2012).

In order to help us see the reciprocation between context and perception, Ihde recommends the phenomenological technique of epoché (a philosophical tool that refers to a suspension of judgement in order to see further), which he illustrates through story telling (which invokes a child-like suspension of belief in order to follow the story's intention). As an example, Ihde deconstructs the Necker Cube, described earlier in this paper (Figure 2. **Necker cube: a multistable figure**). To most viewers, this image offers two obvious interpretations, spontaneously fluctuating between upward- and downward-facing cubes. Ihde helps us see more (see Figure 6. Necker cube: a multistable figure re-interpreted as an insect (second image) and as a curiously cut gem (fourth image). Adapted from *Technology and the Lifeworld*, by D. Ihde, 1990, p. 146. Copyright 1990 by Indiana University Pres.

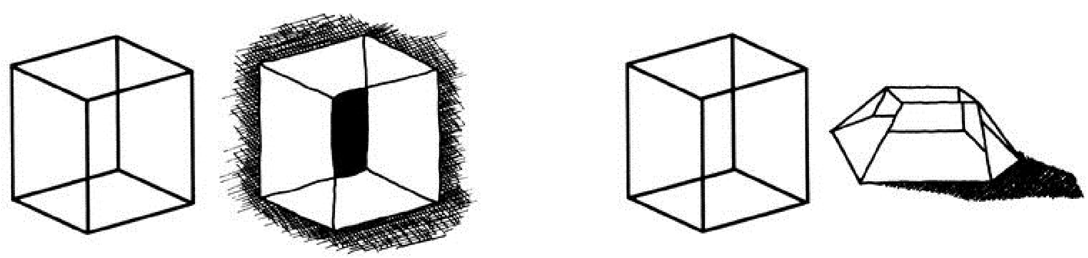

*Figure 6.* Necker cube: a multistable figure re-interpreted as an insect (second image) and as a curiously cut gem (fourth image). Adapted from *Technology and the Lifeworld*, by D. Ihde, 1990, p. 146. Copyright 1990 by Indiana University Press. Reproduced with permission from Don Ihde.

For example, look at the Necker Cube and imagine an insect hanging out in a hexagonal hole (Figure 6, second image). In this case, you must forgo instinctual three-dimensional interpretations, and instead force a two-dimensional interpretation, whereby the parallelogram in the centre represents the insect body, and the six lines emanating from the centre are the six outstretched legs attached to the sides of a hexagram-shaped hole. Or, look again, this time demanding from yourself a non-instinctual three dimensional interpretation: perhaps you can see the figure as a "curiously cut gem" (Figure 6, fourth image). This latter interpretation is itself ambiguous: it can be interpreted in two ways: from the top (as a pyramid whose top emerges out of the page) or from the bottom (as an inverted pyramid whose top falls into the page). Ihde (1990) suggests that complex perceptual multistability, which is "rarely followed" in the psychology of vision, has considerable implications in understanding human-technology relations (p. 146). Like a Necker Cube, many concepts, including technology, lack perceptual stability. We can see a concept from many perspectives, but often we are caught up with particular perspectives. However, once you begin to see the Necker Cube – or technology – through the other possibilities that the phenomenon affords, there is a perceptual shift: it becomes difficult to avoid these new perspectives. And this is good because it reflects a generation of new knowledge.

The common interpretation of technology as neutral and objective is challenged in a similar vein by Andy Clark (2003). Clark believes that biological-technological interfaces systematically subject us to learning. Like Ihde, in Clark's view, organism and environment are intrinsically coupled by evolution. We are "natural born cyborgs" not because we "use" technology in an objective sense, but in "the more profound sense of being human-technology symbionts: thinking and reasoning systems whose minds and selves are spread across biological brain and nonbiological circuitry" (p. 3). For example, when we perform long division on a piece of paper, our reasoning ability extends *through* the pencil and inhabits the piece of paper. Clark urges us to re-conceive the location of mind itself.

**Innis' conception of technology and its cultural consequences.**

Technology can be interpreted further as cultural grammar. It provides form for communication. Thus, technology structures society by organizing power, for example, emphasizing space (e.g. geographic dispersal) and/or time (e.g. sense of history).

Harold Innis (1951) pioneered the study of social, structural, and political consequences of technology. He mentored Marshall McLuhan and presaged the famous dictum that the medium is the message. Both of these social theorists saw that form, above content, has the power to shape culture. For example, the railway created new kinds of cities not because of the freight it carried (content) but because railways (the medium) changed the scale and pace at which humans could operate (McLuhan, 1964, p. 24). In Innis' study of the historical effects of various media across various civilizations, he recognized that heavier and more durable materials (e.g., stone tablets) afford and encourage dissemination of knowledge over time (temporal bias), while lighter materials (e.g., paper) afford and encourage dissemination of knowledge over vast distances (spatial bias). Innis understood that a "relative emphasis on time or space will imply a bias of significance to the culture in which it is embedded" (1951, p. 33).

For example, in a chapter entitled "Technology & Public Opinion in U.S.A." (*The Bias of Communication*, 1951), Innis charts the development and effects of the U.S. newspaper industry. In his account, advances in technology direct society toward a narrowing sense of time. In brief: in eighteenth century America, newspapers emerged to empower opposition to British restrictions. After the American Revolution, freedom of the press was patriotically guaranteed in the Bill of Rights. Politicians soon realized the power of the press as "an instrument of strategy", and this led to newspaper monopolies such that “freedom had become license”, controlled by the elite (Innis, 1951, p. 157). To compete, smaller presses introduced more advertisements, lower prices, and sensationalism, toward a shallower and more disposable press. Then the invention of the telegraph led to a more rapid supply of news, which demanded faster presses and faster circulation. This further weakened centralized control. Political impact continued to wane into the background. Linotype enabled still faster typesetting, which led to daily updates in advertisements. Operations were increasingly controlled by business departments rather than editorial departments. The ability to include illustrations led increasingly to communications directed at the eye. Mass production and interest in commercial prosperity replaced muckraking. “Newspaper civilization had entered the concluding phase of its intensive development in the speculative activity of the [nineteen] twenties. Its bias culminated in an obsession with the immediate” (Innis, 1951, p. 187).

Innis describes cultural technology as a grammar that is spoken by its denizens. He recognizes as an effect of modern technology the disappearance of an interest in time and matters of duration. For example, he saw newspapers and dictionaries as characteristic of the “pervasive influence of discontinuity” (Innis, 1951, p. 191-192). According to Innis, for culture to succeed, we must concern ourselves with a greater capacity “to appraise problems in terms of space and time” and “to take proper steps at the right time” (Innis, 1951, p. 85). “All of Innis’ writings might be interpreted as a recovery of time, of historical remembrance, against the ‘monopolies of space’ (radio, television, newspapers – the detritus of ‘machine culture’) imposed by technological society” (Kroker, 1984, p. 92). Quoting Albert Schweitzer, Innis warns us that “Our spiritual life is disorganized for the over-organization of our external environment leads to the organization of our absence of thought" (Innis, 1951, p. 86). The philosophy of George Grant provides a more nihilistic interpretation of technological deprival: "the loss even of a *sense* of loss of the human good" (Kroker, 1984, p. 14, emphasis original). The critical analyses of these philosophers of technology foreshadow the popular thesis that Nicolas Carr puts forward in *The Shallows: What the Internet is Doing to Our Brains* (2010). Carr similarly problematizes the effect of organizational technology on human cognition, namely, the purchase of immediacy for the price of depth. In these accounts, cultural processes (technologies) can be seen to systematically modify individuals by providing us with new tools (technologies) that are at once hard to resist and hard to bear.

To drive the point home: the anthropologist Jack Goody describes writing as a technology that systematically affects how and what we learn. According to Goody, writing is different from spoken language: "Writing gives the mind a special kind of lever on 'reality' … a change in 'capacity' … The graphic representation of speech … is a tool, an amplifier, a facilitating device, of extreme importance" (Goody, 1977, p. 109). Specifically, says Goody, writing enables: abstraction and de-contextualization, over-generalization and classification, explication and crystallization of discontinuities, an appearance of authority. As an example of its effects, Goody describes how, by leveraging visual abilities for pattern recognition, writing alone supports the creation of taxonomies and lists. In an entirely oral culture, "it would be extremely difficult to formulate a series (a patterned list) without first turning aural statements into visual ones, just because in the scanning of informational input the eye operates quite differently from the ear" (Goody, 1977, p. 105). Additionally, in an oral-only culture, which emphasizes experience and continuity, taxonomic inventories lack relevance. Imagine asking a caveman if a tomato is a fruit! While trivial, in our culture of writing, the tomato-fruit question emerges as valid, its answer apparently real.[25]

Innis warns us that "as modern developments in communication have made for greater realism they have made for greater possibilities of delusion. … We are under the spell of Whitehead's fallacy of misplaced concreteness." (1951, p. 82)[26]. In other words, by supporting abstract rationalism, generalized classifications, and crystallisation of discrete thoughts, the written word sanctions a false appearance of certainty. The word can be mistaken for an authority. Thus the written word lends itself to power structures.

***Educational Technology – Literature Review***

The previous sub-sections described conceptions of education and of technology, independently. These descriptions are intended to inform, but not to replace, the current sub-section. As a unified construct, "educational technology" is different than the sum of its parts. ET represents a professional field and practice as well as a concept. However, definitions of ET are fuzzy and inconsistent, even to practitioners of ET.

Educational technologists appear to differentiate themselves from other pedagogues primarily by placing more value on the use of technology. The question of what constitutes technology is subject to interpretation. Hard technology and soft technology are both implicated. Hard technology refers most often to computer hardware and software, esteemed tools which are easy to objectify. Soft technology refers generally to processes and ways of thinking, ideas which appear less objective and more difficult to

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[25] In our culture, the answer is actually ambiguous: "Scientifically speaking, a tomato is definitely a fruit … but it's used as a vegetable in cooking" – http://oxforddictionaries.com/words/is-a-tomato-a-fruit-or-a-vegetable

[26] Whitehead's "fallacy of misplaced concreteness" refers to the mistaken conception that abstract ideas correspond to definite realities in space and in time; Whitehead's analysis resembles criticisms against representational theories of mind, picture theories of language, and spectator theories of knowledge.

de-contextualize from the systems in which they are embedded. Unlike hard technologies, soft technologies are difficult to understand without systemic interpretation, which affords deeper revelation of theoretical, cultural, and subjective consequences. Unfortunately, while soft conceptions of technology enrich ET practitioners' skill sets, a review of the literature reveals a popular bias toward hard conceptions of technology.

The first sub-section below provides an historical review of the ET field and its evolving definitions. This history is culled primarily from literature provided by the Association for Educational Communications and Technology (AECT), which is the oldest professional and academic association related to ET (Hlynka & Jacobsen, 2009). I also include criticisms, commentaries, and additional definitions from various ET practitioners. Many of these definitions of ET converge on the importance of soft conceptions of technology, including emphases on processes. The following sub-section describes over-emphases on hard conceptions by practitioners in the field of ET. This review includes: a search across peer-reviewed journal articles in the Education Resources Information Center (ERIC), an analysis of the 2010 National Education Plan published by The U.S. Office of Educational Technology, and deconstruction of the Technological Pedagogical Content Knowledge (TPACK) approach, which is designed to help teachers integrate technology into classrooms. Then, in the next sub-section, I return to the literature to review soft conceptions of technology. Some of these soft technology conceptions also appear problematic, unambiguously situating intellectual knowledge ahead of technological processes, which deemphasizes the potential for technology to produce new intellectual knowledge. I conclude this section with limitations and thoughts for future theories of ET.

**History of ET and its definitions.**

According to the AECT Definition and Terminology Committee chair, Alan Januszewski, ET has invested more time and energy trying to define itself than any other field (Januszewski, 2001; Januszewski & Molenda, 2008). Januszewski and Molenda (2008) suggest two primary reasons for this investment: practitioners' desire to stake out a professional niche, and a desire for legitimization through "certainty in the meaning and use of terminology in our field" (p. 348). By the strictest of standards, Januszewski (2001) suggests that no dictionary definition meets its formal criteria, that is: the inclusion of everything that belongs in its description and the exclusion of everything that does not belong. Luppicini (2001) and Januszewski (2001) both agree that the creation of an authoritative ET definition appears to be a political act. Definitions are not value-neutral. Definitions reflect choices.

The following historical review of the ET field and its evolving definitions borrows heavily from texts by Januszewski (2001) and Januszewski and Molenda (2008). Theories of ET began to germinate in the early twentieth century, alongside a growth in audiovisual (AV) instructions and the development of instructional psychologies such as Edward Thorndike's connectionism (Januszewski, 2001; Luppicini, 2007). Efficiencies in industry further motivated an application of science and engineering techniques to the field of education; for example, Charles Taylor's management style contributed to an assembly line view of education (Januszewski, 2001). The application of science was viewed from at least three differing perspectives: some instructors followed the view espoused by G. Stanley Hall, in which curriculum research should occur in natural environments to better align with children's natural behaviour; some followed Dewey's view that science should be modelled as an active process of reflective inquiry; and many adopted the simplistic approach of using science as a means for precise and predictable standards and measurements in education (Januszewski, 2001, p. 12).

James Finn, an early proponent for a professional field of ET, advocated for a systems approach to instructional problems (Beckwith, 1988; Luppicini, 2008; Reiser & Ely, 1997;). Finn (1962) sympathized with Dewey's rich conception of science and technology. For example, he wrote that "Dewey suggested that we live in a technological, industrial culture and that technology was, in fact, the main determinant of its direction … ends and means are inseparable … ends become means to further ends" (Finn, 1962, p. 32). Finn's perspective, like Dewey's, is sometimes confusing. For example, Januszewski (2001) points out Finn's non-intuitive description of "automation": Finn ambiguously suggests that automation *is* technology and also *includes* technology (Januszewski, 2001, p. 23). The idea that technology (i.e. automation) includes itself (i.e. other technology) demands contemplation through multiple systemic levels. Finn describes "automation in education" not as "a manless, machine-operated production", but instead as a systemic "way of thinking involving patterns and self-regulation" and including "long-range planning" and "wise decision-making" as well as other technologies (Januszewski, 2001, p. 23). This appears analogous to Dewey's distinction between habituation and habitual adaptation. Automation, interpreted superficially, suggests habituation (mindless repetition); however, Finn's concept of automation, interpreted deeply, suggests habitual adaptation (learning).

Finn's emphases on processes and systems theory influenced the first formal definition of the field, which was attributed not to ET but to "Audiovisual

Communications" (under the auspices of the Department of AudioVisual Instruction, DAVI). The ***1963 DAVI definition of ET*** reads: "Audiovisual communication is that branch of educational theory and practice concerned primarily with the design and use of messages which control the learning process" (as cited in Reiser & Ely, 1997, p. 65). This definition emphasized messages over mediums, informed by learning theories (including Skinner's behaviourism) and communication theories (most notably the Shannon-Weaver model of information communication). This definition was criticized for implications of "control," for emphasizing esoteric theories of communications, and for not giving enough authority to curriculum designers (Januszewski & Molenda, 2008, p. 265).

The next definition referred explicitly to ET (rather than AV) as the Association for Educational Communications and Technology (AECT) came to replace DAVI in 1970. The full version of the ***1972 AECT definition of ET*** is eight pages long; here is the short version: "Educational technology is a field involved in the facilitation of human learning through the systematic identification, development, organization and utilization of a full range of learning resources and through the management of these processes" (Januszewski, 2001, p. 49). The 1972 definition highlights several themes: (a) an continued emphasis on a systems approach; and (b) greater emphasis on physical resources as compared with processes; (c) the use of the word "field" implies the inclusion of numerous theories; and (d) human-centered instruction is implied (influenced by Carl Rogers' humanistic psychology and Ivan Illich's indictment of school as "mechanistic social credentialing centers") (Januszewski, 2001). According to Januszewski and Molenda (2008), the de-emphasis on processes was a setback for the profession, impelled by a 1970 Presidential Commission on Instructional Technology, which favoured attention on hardware (p. 266).

As the field grew, the AECT expanded the ET definition to 16 pages. Here is an excerpt of the ***1977 AECT definition of ET***: "Educational technology is a complex, integrated process, involving people, procedures, ideas, devices and organization … involved in all aspects of human learning" (Januszewski, 2001, p. 78). The new definition of ET was designed not to limit the field of possibilities. It provided a broad perspective of Learning Resources ("Messages, People, Materials, Devices, Techniques, and Settings") as well as Educational Development Functions ("Research Theory, Design, Production, Evaluation Selection, Logistic, Utilization, and Utilization Dissemination") and Educational Management Functions ("Organizational Management and Personnel Management") (Januszewski, 2001, p. 78). By re-emphasizing processes, the 1977 definition authors rejected the 1970 Presidential report; they intended for ET to be understood as a theoretical construct, as a field (a collection of theories), and as a profession; and, by infusing the definition with systems concepts, the authors implied that the use of systems concepts itself is a process (Januszewski & Molenda, 2008). Unlike previous definitions, the 1977 definition discriminates between Educational Technology and Instructional Technology (IT): ET referred broadly to all human learning, while IT was understood as a subset of ET, designated specifically for controlled and purposed learning situations. Concerning the relationship of ET to theory, Januszewski and Molenda (2008) point out three possible interpretations: (1) ET is a theoretical construct, (2) ET is a theory, and (3) the definition of ET is a theory; they suggest that these interpretations, while each valid in its own way, are not interchangeable.

The next overhaul of the ET definition focussed on simplification and professionalization because the 1977 definition was deemed to be too complex and too general: it appeared to equate ET with all of education; practitioners had difficulty adopting the whole of it, broke the integrated systems theory to pieces in their citations, and disregarded many components, including the distinction between ET and IT (Januszewski, 2001). The perceived need to stake out the profession led to a switch in the field's label, from ET to IT. The ***1994 AECT definition*** reads: "Instructional technology is the theory and practice of design, development, utilization, management, and evaluation of processes and resources for learning" (Januszewski, 2001, p. 103). The new definition still included an implicit focus on systems theory and an explicit focus on processes. No new concepts were introduced. The authors of this definition concede that ET and IT are synonymous, and while most professionals use the ET and IT labels interchangeably, IT had become more popular, appeared more precise, emphasized learning with instruction (as opposed to incidental/unintentional learning), and implied more settings for practice, which differentiated the profession from traditional education.

Most recently, as a result of changing educational theories and settings (including the growth of constructivist practices, the widespread adoption of computers in traditional classrooms, and perceived limits on the field's stake), the AECT published a new book and definition in 2008. The ***2008 AECT definition of ET*** reads: "Educational Technology is the study and ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources" (Januszewski & Molenda, 2008, p. 1). (See Figure 7. A visual summary of key elements of the 2008 AECT definition of ET.) In this definition, the AECT reverted to the ET label. Lowenthal and Wilson (2010) criticize this reversion on several grounds: more job postings and existing program titles refer to the previous IT label; to revert to ET is indicative of the field's identity crisis; and "a thorough justification for the change cannot be found in the book – leaving readers to piece together some kind of grounds for the decision" (p. 40).

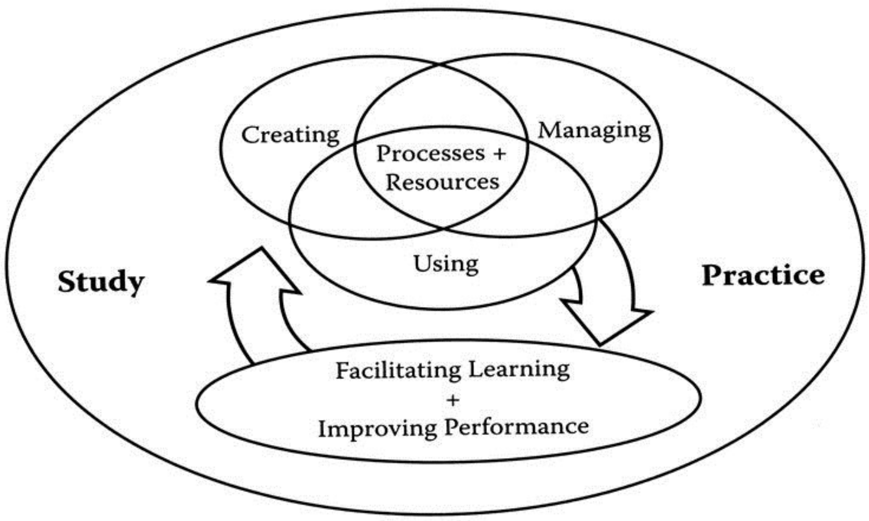


*Figure 7.* A visual summary of key elements of the 2008 AECT definition of ET. Adapted from *Educational technology: A definition with commentary* by A. Januszewski and M. Molenda, 2008, p. 333. Copyright 2008 by Routeledge.

Silber applauds the AECT's continued efforts in their latest ET definition "to use the correct definition of the word 'technology,' and to de emphasize the 'stuff' of our field as the raison-d'etre of the field" (Richey, Silber & Ely, 2008, p. 24). In their commentary on the new definition, Hlynka and Jacobsen (2009) concur that "Educational technology is not a tool: it is a study and practice. Not only that, it is, by definition, an ethical practice." They lament the fact that "most often, the concepts default into issues of hardware, tools and things" (2009).

Januszewski and Molenda (2008) acknowledge that other definitions and conceptions of ET exist beyond the AECT definitions, that the current AECT definition is only a “snapshot” in time, and that “when looked at from this perspective, when it comes to educational technology, we may never really know what we are talking about” (p. 349). Donald Ely writes that definitions are starting points for dialogue, not end points. Ely suggests that definitions are “arbitrary conveniences – neither true or false” (Richey et al., 2008, p. 24). He encourages researchers to engage in dialogue, to establish their own definitions. Lowenthal and Wilson (2010) agree with Ely that the definition should continue to grow through dialogue.

**Conceptions of ET in terms of hard technology.**

A simple approach to technology is to assume that it refers only to hard technology. Evidence of this convenient interpretation is apparent through a review of literature related to educational technology. In this sub-section, I provide three contemporary cases. First, in two recent U.S. government publications, all references to technology refer to hard technology. This is alarming, especially in light of Januszewski and Molenda’s (2008) comments that professional associations such as the AECT have historically struggled against dominant governmental discourse (see, for example, the 1972 and 1977 AECT definitions of ET). Second, a search amongst peer-reviewed articles in ERIC reveals bias toward hard technology interpretations in academic research. Third, I investigated TPACK, an oft-cited framework that attempts to help teachers integrate technology into classrooms; this framework clearly implies that knowledge of technology relates exclusively to knowledge of hard technology.

***U.S. Government publications.***

The 2010 U.S. National Education Plan (published by the Department of Education's Office of Educational Technology) contains hundreds of references to technology. These references each implicitly relate technology exclusively to computers or computer-related resources. For example, the authors write that outside of school, students lives are "filled with technology" that enables "mobile access to information and resources 24/7", the creation of "multimedia content", and participation in "online social networks and communities where people from all over the world share ideas" (p. 9). Their description suggests that technology "connects" students to ideas through hardware. However, ideas (and thinking processes) are themselves not recognized as technology. In a graphic illustrating "a model of learning, powered by technology", the icon for technology is a laptop computer, which connects the student to online networks of tools, peers, and data (p. 11). The authors write that "technology dominates the workplaces of most professionals and managers in business" and provide as examples: physicians' use of "mobile Internet access devices to download x-rays and test results", geologists' use of "underground sensors along fault lines", filmmakers' use of "everyday computers and affordable software for every phase of the filmmaking process" (p. 9). While the authors caution against utilizing technology for the "automation" of existing processes and procedures, recommending instead "fundamental structural changes that technology enables" (p. 64), the implicit connotation remains that "technology" equals "hard technology". This is evident for example, in their reference to "technology purchases" (p. 65). It appears unlikely that the authors refer to purchases of immaterial processes, for example, payments toward patent holders (the only reference in the document to intellectual property refers to “open educational resources” in the public-domain, which range from “podcasts to digital libraries to textbooks, games, and courses, and they are freely available to anyone over the Web”; p. 56).

A similar conception of technology is evident in a 2008 document entitled “Educational Technology in U.S. Public Schools”, published by the U.S. Department of Education. The document summarizes results from “district, school, and teacher surveys on educational technology”, specifically revealing “data on availability and use for a range of educational technology resources, such as district and school networks, computers, devices that enhance the capabilities of computers for instruction, and computer software” (p. 1). No mention is made with respect to ET resources such as intellectual methods or styles of thinking. In fact, the authors provide the following succinct definition of technology (p. B-11):

> Technology: Information technology such as computers, devices that can be attached to computers (e.g., LCD projector, interactive whiteboard, digital camera), networks (e.g., Internet, local networks), and computer software. We specifically are not including non-computer technologies such as overhead projectors and VCRs.

The fact that the U.S. Office of Educational Technology in specific, and the U.S. Department of Education in general, each defines “educational technology” strictly in relation to hardware suggests that we need to review national conceptions of ET.

***ERIC references.***

Bias amongst scholars toward a hard interpretation of technology is evident in the Educational Resources Information Center (ERIC). I sampled two hundred peer-reviewed journal articles published in 2012 and indexed under the ERIC thesaurus descriptor, “educational technology” (See Appendix A). I limited my analysis to a cursory search across abstracts and additional descriptors for these articles. I neglect the nuanced research efforts of these authors (I imagine that all of them implicitly or explicitly attend to the dynamic complexity of learning processes). My interest here specifically relates to their use of the term "technology". My question is: what does each researcher mean by the term "technology"? I found that 166 of 200 articles (83%) appear to use the term technology in reference to the use, management, or creation of "hard technology". Soft technology appears underutilized as an ET conception.

***TPACK conception of technology.***

Of the 200 articles I reviewed for the previous sub-section, five are related to the technology pedagogical content knowledge (TPACK) framework, in which technology is understood strictly as hard technology. The framework provides teachers with supplemental pedagogical knowledge in order to augment technology knowledge (e.g. Harris & Hoffer, 2011). Supplemental knowledge is required in the TPACK framework because, in their conception, "technology knowledge" entirely excludes knowledge of soft technologies. In the TPACK framework, technology knowledge refers only to knowledge of hard technologies and the skills by which hard technologies are used.[27]

The TPACK conception of technology can be contrasted with the AECT conception of technology. In the TPACK conception, pedagogical knowledge informs teachers about the affordances and limitations of hard technology. In the AECT conception, on the other hand, technology is understood ambiguously as hard technology and as soft technology, including intellectual processes and skills. As a result, according

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[27] According to an author of the TPACK framework: "Technology knowledge is knowledge about standard technologies such as books and chalk and blackboard, as well as more advanced technologies such as the Internet and digital video. This would involve the skills required to operate particular technologies.", from http://mkoehler.educ.msu.edu/tpack/technology-knowledge-tk, retrieved 2012-10-08

to the AECT, pedagogical theories naturally infuse the design of educational technologies, so artificial separation between pedagogy knowledge and technology knowledge is overcome. (See Figure 8. Conceptions of technology: TPACK versus AECT.)

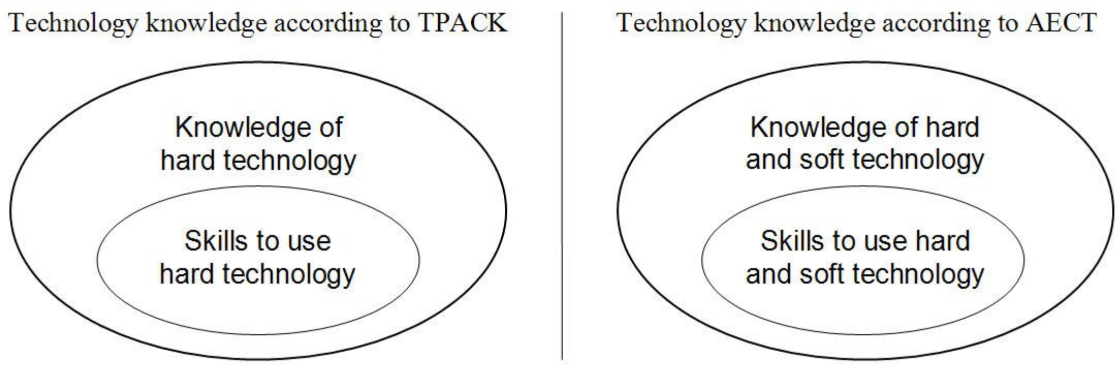


*Figure 8*. Conceptions of technology: TPACK versus AECT. TPACK authors imply that "technology knowledge" includes: knowledge of hard technology and the skills to use that technology. AECT authors imply that "technology knowledge" includes: knowledge of both hard and soft technology and the skills to use both hard and soft technology.

**Conceptions of ET in terms of soft technology.**

Soft technology refers to process conceptions of technology, including procedures, theories, and practices. This conception is advertised by many, including Concordia University's Department of Education, who write in their ET Master of Arts programme booklet: "Educational technology is a rapidly growing field that generally refers to the application of processes and styles of thinking developed outside the field of education to solving educational problems". Despite testimonials, advocates agree that the process conception of ET is commonly misunderstood or ignored (e.g. Finn, 1962; Januszewski, 2001; Luppicini, 2005; Januszewski & Molenda, 2008; Richey et al., 2008; Hlynka & Jacobsen, 2009). The complexity of ET leads naturally to its ambiguity, which is often not tolerated, such that ET is misunderstood in favour of more certain terms, particularly, in terms of objects. For example, Luppicini (2005, p. 105) writes that defining ET as a process:

> creates dissonance between the popular notion of technology as state-of-the-art equipment and the older idea of technology as a process. This dissonance surrounding technology gives rise to definitions that are not easily understood within the field or widely embraced outside of the field.

Indeed early leaders in the field stressed that "technology is not, as many of the technically illiterate seem to think, a collection of gadgets, of hardware, of instrumentation" – rather – "technology is, fundamentally, a way of thinking" (Finn, 1962, p. 29/33). As the definition of ET evolves, the AECT continues to emphasize this important process conception.

The AECT definition of ET accentuates "intellectual" processes as technical procedures or actions that develop human capability (Januszewski, 2008, p. 196) (see also Figure 5. The AECT's Input – Process – Output paradigm**. Adapted from *Educational Technology: A Definition With Commentary* by A. Januszewski and M. Molenda, 2008**). The input to such a process can include information, conditions, and situations. The output is either a product (for example, an idea) or another process. The process transforms input to output. The AECT describes this process as "intellectual" because it is intentionally conceived in the mind. However, the AECT demarcation of intellectual processes and non-intellectual (cognitive, biological, and spiritual) processes reveals a bias toward intellectual intention.

Earlier, I described three philosophical conceptions that displace technological processes from intellectual foundations: according to Dewey, technological inquiry is made by experience; according to Ihde, biology and technology interface symbiotically; according to Innis, technology provides cultural form for intellectual content. While, in theory, we can always intellectualize a process *a posteriori*, these philosophers suggest that technological processes are not necessarily intellectual *a priori*. In fact, experiential, biological, and cultural processes stimulate new possibilities for intellectualization.

Engaging with complex interpretations of educational processes enables educational technologists to enter into productive inquiry toward the creation of new means for learning (for both ourselves and our learners). One way to manage the complexity of social science is through systems theory, which has many advocates in ET (for example, the AECT). A systems approach models complexity by: acknowledging multiple levels, contexts, and perspectives; accommodating unpredictability and interdependency; and striving to interrogate real, social situations. Furthermore, a systems approach "forces experts to question system boundary conditions, changing conditions, and whether or not it is possible to ever arrive at lasting truths in the world" (Luppicini, 2005, p.106). In other words, a systems approach encourages the development of warranted assertions over the development of certainty.

That the intellect precedes ET has met with healthy scepticism. For example, some argue that ET is preceded not only by science, but also by literature and the arts (Luppicini, 2005; Solomon, 2000). Others wonder how a technology that is "preauthenticated" by the intellect faithfully predetermines correspondence between tasks in a learning environment and tasks in a learner's real world, a "world that is constantly being shaped and reshaped by learners working within their own experiences" (Petraglia, 1998, p. 60). Petraglia (1998) insists that constructivist processes, materials, and "rules of thumb" must be supplemented with flexible and ongoing dialogue between educators and learners. He points out that the only norm is change, so educational technologists must support “both the dialogic dimensions of learning and the ambiguity that infuses knowledge” (Petraglia, 1998, p. 63).

Some conceptions of ET, by design, are ambiguous, complex, and wide open to interpretations at multiple levels. In Hlynka and Jacobsen’s (2009) perspective, technology is generally “a means to fulfill a human purpose”, and it consists of the “entire collection of practices and devices available to a culture” (Arthur, as cited in Hlynka & Jacobsen, 2009). According to Luppicini (2005, p. 105), key themes in ET include emphases on adaptive, systematic, or transformative processes that facilitate human needs, as well as mental, environmental, and social influences. Finn (1962) writes that “as the perceptive students of general technology continually insist, technology in society is an organic process” – which is not an intuitive concept: “qualitatively and psychosomatically different from any ever held before” (p. 32). In an attempt to find the right words, Finn (1962, p. 32) quotes Hannah Arendt who quotes Werner Heisenberg:

> general technology is no longer “‘the product of a conscious human effort to enlarge material power, but rather like a biological development of mankind in which the innate structures of the human organism are transplanted in an ever-increasing measure into the environment of man.’”

While certainly more challenging to grasp (in comparison to simpler hardware interpretations), these extended interpretations more fully develop the picture of technology’s potential in education.

### *Conclusion – Toward a Theory of Educational Technology*

Educational technology is clearly an ambiguous concept. The field and its definitions have evolved and will continue to evolve. Various interpretations exist today. A convenient and populist interpretation defines ET in terms of hard technology. This narrow interpretation has been perpetuated in academic and political discourse. Some researchers acknowledge that this limited picture of ET neglects important process interpretations. In terms of processes, ET can be interpreted as styles of thinking, ways of organizing, methods of managing, or even automation (in the sense of Finn's habitual adaptation). These pictures are richer. However, when these processes are understood as intellectual products, then these pictures are still limited. Indeed, the intellect does inform technology; however, technology can also inform the intellect. Technology permeates our immediate experiences, modifies our biology, and provides the ground for cultural evolution. Philosophers recognize that these reciprocal and recursive processes modify our intellect and alter our very being. While non-intellectual processes (such as biological processes) can be intellectualized, this does not imply that the processes themselves are intellectual.

Educational technologists are well equipped when they acknowledge novel aspects of technology; they are ill-equipped to encourage growth when interpretations of technology are limited to existing hardware or to prior knowledge of processes. So why do these limited interpretations dominate? Why is hard technology over-emphasized or as Januszewski's (2001) asks: "if educational technology is a process, as the majority of the members of the AECT view it, then why does most of the history that is written about it focus on the hardware and equipment that is used in the field?" (p. xxiii). This dominant discourse emerges from multiple causes. First, Januszewski describes a desire for conceptual and professional legitimization of ET through an emphasis on "objectivity, permanence, and exact standards" (p. 115). These characteristics correspond neatly with popular notions of standardized machines and computer technology. As a result, a cognitive bias related to representativeness (overemphasis on similar characteristics) may obscure deeper interpretations of technology. Second, at a cultural level, research disseminated by the U.S. Department of Education (for example) substantiates the dominant discourse of ET as hard technology. Researchers must struggle against this authoritative voice. When researchers fail to acknowledge the limitations of a problematic discourse, the discourse is amplified, resulting in a positive feedback loop that further dampens resistance. Third, at a subjective level, we find it much easier to refer to "things" in comparison with "processes". Processes are inherently more complex to describe. For instance, in a model of a network (for example, a concept map), it is always easier to label the nodes (objects) in comparison to the links (processes). When we label a node, its label appears to have a tangible, physical correlate; it appears to correspond to ontological substance (city, person, idea). When we label a link, the correspondence lacks substance: processes are intangible, more ambiguous, subject to numerous perspectives.[28] Finally, the Deweyan notion that an idea *is* a technology is not particularly intuitive. It demands critical philosophical reflection: we must relinquish our routine commitment to the ontological precedence of knowledge to technology.

The AECT correctly emphasizes processes throughout their history of ET definitions. But why do they limit their inclusion to "human made processes that systematically apply scientific knowledge", neglecting "nontechnical processes, such as cognitive processes, biological processes, and spiritual processes" (Januszewski & Molenda, 2008, p. 197)? In their attempt to theorize the ET practice (and legitimize the field), the AECT attempts admirably to corral a definition. They try to circumscribe what is, and what is not, in the purview of ET practitioners. Cognitive, biological, and spiritual

[28] Link labels may change or vanish depending on cardinality and temporal perspective. For example, numerous links may exist between the nodes "city" and "person": "city *is birthplace of* person", "city *was visited by* person" (past tense), "person *lives in* city", "person *was born in* city", etc.

processes appear beyond our purview. One could argue, however, that by deliberately leaving these "nontechnical" processes out of practical purview, the AECT perpetuates a limiting theory: they advocate for pre-authenticated knowledge regarding which processes are technical and which are not. In fact, such knowledge is constructed: the demarcation between technical (human-made) processes and non-technical (natural) processes is subject to interpretation. Biological processes (for example), can be interpreted as "human-made" in at least two different ways. One, biological processes are "intellectualized". That is, we grasp these non-intellectual processes at an intellectual level: they are understood as processes because we interpret them. Two, biological processes can be altered: evidence from contemporary neuroscience reveals that our ideas and actions literally modify our brains. Therefore, these processes are within ET purview.

The ultimate goal of the educational technologist is, in Beckwith's words, "to create the means to realize the ideals of learning" (1988, p. 15). To approach this lofty goal, practitioners must engage the complexity of processes. Rather than succumb to a desire for pre-validation, scientist-practitioners must engage in the very process of validation. Growth implies moving beyond what already exists in the intellect. Growth requires trust and sensitivity to inquire and intellectualize further. When one is securely motivated toward habitual adaptation, then one is free to approach new horizons. This ability to look further precedes learning.

## Conclusion – The Relevance of Tolerance of Ambiguity to Educational Technology

The present research serves to clarify the ambiguity that is inherent in two social science concepts: "tolerance of ambiguity" (TA) and "educational technology" (ET). In the preceding section, I have argued that ET must be interpreted as more than the application of hardware. For purposes of learning, ET also implicates various ideas, including styles of thinking. With regard to TA, I have shown that TA can be interpreted as more than a stable trait. TA can be understood also as a style of thinking: a strategy that is situated in a larger process of metacognition, which enables receptivity to novel aspects and alternate interpretations of a given phenomenon, toward conceptual change and learning. From these two conclusions – that ET includes styles of thinking and that TA is a style of thinking – I suggest, therefore, that TA can be interpreted as a type of ET. In the remainder of this paper, I will elucidate this theory.

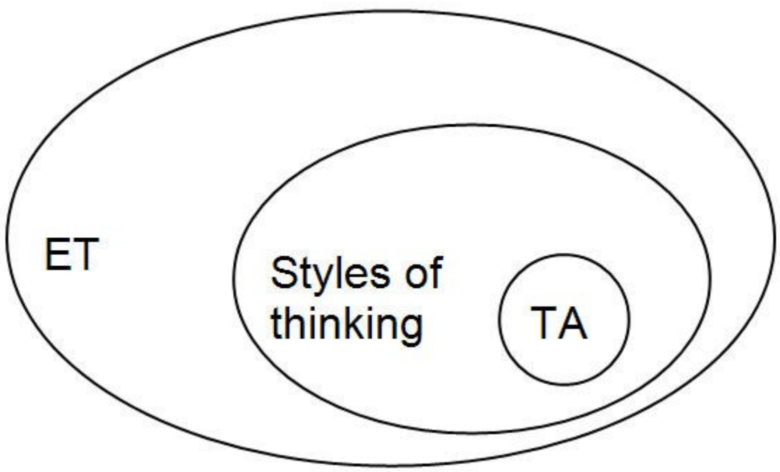


*Figure 9.* TA, understood as a style of thinking, can be interpreted as a type of ET.

TA is most productively theorized as a skill, which exists within the realm of metacognition. Specifically, when a learner experiences a conflict that reduces certainty in existing knowledge, TA serves in the receptivity of new interpretations, toward conceptual change. An engagement with TA depends on sensitivity to novel aspects of phenomena, which requires motivation and trust to surpass existing knowledge. Motivation and trust depends both on the individual and on environmental affordances.

Environmental affordances are in the purview of ET practitioners, as are theories related to metacognition and self-regulation. The design of learning support systems can nurture and support the sensitivity, motivation, and trust that are required for learners to entertain radical conceptual change. Furthermore, ET support systems can involve technology in the broadest sense. While cognitive, biological, and cultural processes are themselves not intellectual processes, they can be grasped mentally and experienced subjectively, and therefore integrated into ET theory and practice. If we assume that all knowledge is grounded in experience, then, at a phenomenological level, ET must balance experience with pre-authenticated knowledge.

Philosophical theories like those of Dewey and Wittgenstein suggest that all phenomena are necessarily ambiguous: interpretations of phenomena are evaluative experiences. While the methods of science can lead to critical consensus, theoretical models of reality nevertheless exist as constructed reports, subject to change as conflicting evidence and competing theories emerge. A program of “critical transparency” demands that we question dominant discourses related to science and technology, in part through a careful analysis of its history and practice.

In an attempt to tolerate the ambiguity of two social science constructs, TA and ET, I have used three levels of analysis. Specifically (inspired by Mischel, 1973), I chose to differentiate theoretical, ecological, and phenomenological perspectives, each of which affords different insights into the interpretation of a phenomenon. Of course, the boundaries between these perspectives are artificial: these perspectives are interrelated and interdependent. Nevertheless, these perspectives serve as conveniences in order to illuminate variability in interpretations of a phenomenon. In the following paragraphs, I recursively cast these three interpretative perspectives toward an enlightened understanding of behavioural acts of interpretation. For example, as an intellectualized concept, "an act of interpretation" itself, can be understood as ambiguous: one can re-interpret the phenomenon of "an act of interpretation" at multiple levels (see Figure 10).

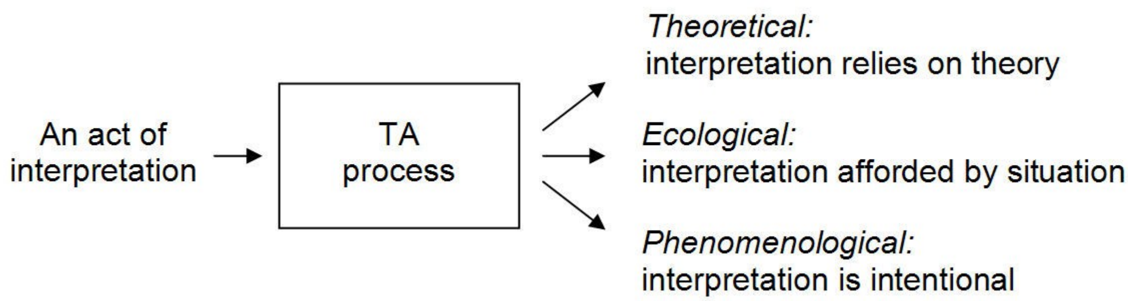


*Figure 10.* Example of interpreting "an act of interpretation" at three levels.

The Necker Cube provides perhaps a simpler case (see Figure 11. Example of interpreting a Necker cube at three levels.). In theoretical terms, the Necker Cube is a flat two-dimensional image that provokes spontaneous three-dimensional interpretation. By design, the image is "multistable": our perception spontaneously fluctuates between two interpretations (with the cube oriented either upward or downward). We might hypothesize that human vision is biologically or culturally attuned to three-dimensional interpretations, which helps to explain, in theory, the spontaneous fluctuations that we experience. Additionally, we recognize that Ihde's storytelling provokes further interpretations, which suggests that our experience (interpretation) of the image can be altered through situational affordance: when he describes the image as a six-legged bug, we are able to re-interpret the image that way; and then again as a curiously cut gem. However, Ihde's interpretative instructions must be collaborated with subjective effort, including our motivation, trust, and phenomenological sensitivity. The act of interpreting the Necker Cube can be understood from each of these three levels – in theoretically objective terms, with regard to environmental affordances, and with respect to subjective intentionality. Each of these levels can be seen to afford unique insight into how we conceive of a Necker Cube. Each of these levels can also be seen to interrelate.

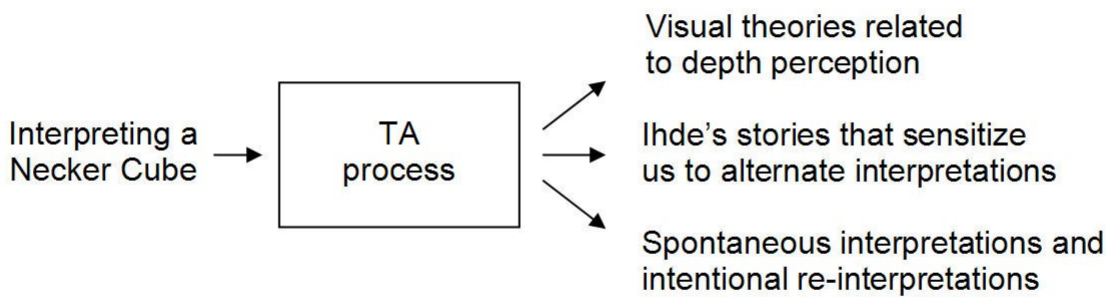


*Figure 11.* Example of interpreting a Necker cube at three levels.

Analogously, interpretations of ET and of TA can be understood at multiple levels. Interpretations of ET (see Figure 12) can occur at a theoretical level; for example with regard to hard and/or soft technology (I have argued that theorization of ET demands inclusion of soft technology). At an environmental level, ET can be interpreted in relation to cultural discourses. As one example, government publications refer to ET as if it were restricted to hard technology; this limited affordance can be supplemented by exposure to AECT definitions. Simultaneously, ET is interpreted subjectively by practitioners and consumers of ET. We experience the use of materials and ideas in our own education and in the educational interventions that we design. Our beliefs shape our experiences; our beliefs are informed by ET theories and culture. Taken individually, none of these three interpretations appears complete on its own. Each of these perspectives enriches the act of interpreting ET. Certainly more interpretations are possible; these are merely examples.

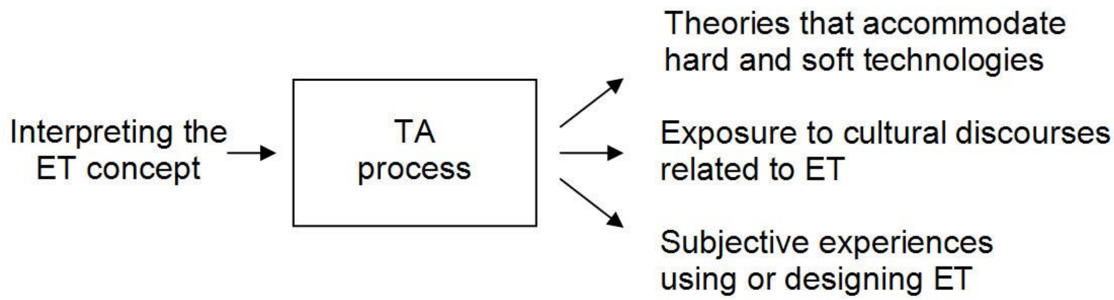


*Figure 12.* Example of interpreting ET at three levels.

Likewise, one's understanding of TA can be contemplated at multiple levels (Figure 13). Theoretically, TA can be understood as a general or situation-specific trait and also as a metacognitive process (I have argued that an interpretation of TA as a metacognitive process provides the richest theorization). At an environmental level, we acknowledge that construction of the TA concept can be limited, for example, by cultural beliefs related to the stability of personality. I found my own understanding of TA to be supplemented when I discovered Merenluoto and Lehtinen's (2004) progressive theorization. Subjectively, overt experiences of TA reveal its metacognitive potential, provided that we are sensitive to the conflicting notions inherent in the phenomenon that we are interpreting, and depending on our motivation to work through the conflict. The current exercise, while simplistic, represents one such overt experience.

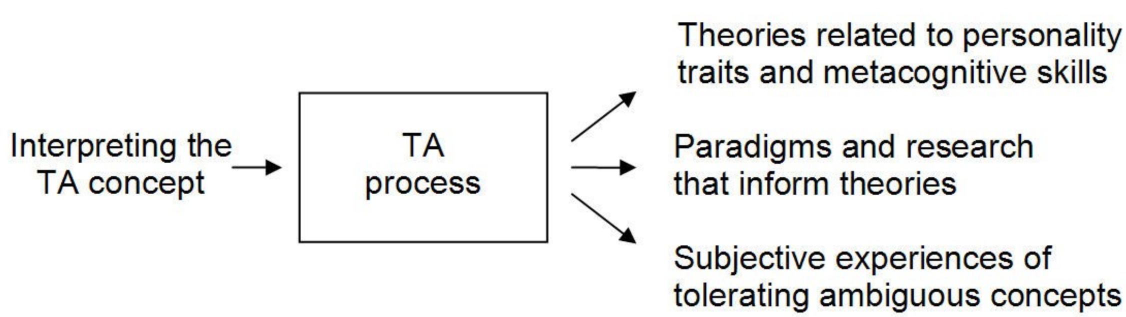


*Figure 13.* Example of interpreting TA at three levels.

Some interpretations are spontaneous; others require effort. Some phenomena appear to enjoy fixed and permanent interpretations; however, this is unusual. Even paradigmatic scientific constructs are subject to re-interpretation. The molecular status of helium provides a strong example of conceptual ambiguity. In the present research, I suggest that the social science constructs, TA and ET, are each ambiguous, admitting numerous possibilities for interpretation. Some interpretations are limited and debilitating.

To limit TA to a trait undermines study of its development as a metacognitive process. To limit ET to the application of hard technologies neglects the relevance of ideas and processes. To extend ET to include intellectual processes is good, yet evades the very construction of those processes through cognitive, cultural, biological, and technological means. Sensitization to these alternate interpretations is not guaranteed. Conceptual change requires motivation and trust, must be nurtured, and takes time.

While the present research can be viewed as an application of TA toward richer construal of TA and ET, other applications await. For example, TA can be applied against one's interpretation of what constitutes a successful educational intervention. The theory of "productive failure" (e.g. Kapur & Bielaczyc, 2011) provides an interesting, counter-intuitive case, the interpretation of which benefits from TA. On the one hand, an unscaffolded learning experience related to an ill-structured task can be deemed an outright "failure" due to participants' abysmal performance. On the other hand, longitudinally, it may be a "success" due to hidden efficacies. The ambiguity of the process is brought to light.

As another example, several researchers emphasize the productive use of ambiguity toward advanced understandings in mathematics (Byers, 1999; Byers; 2011; Grosholz, 2007). According to them, math is not merely formal logic; it is tacit and experienced. Like Merenluoto and Lehtinen (2004), these researchers suggest that, in order to appreciate and utilize the creative potential of mathematics, learners must first tolerate multiple interpretations of various concepts. Byers (1999) points out the ambiguity of: square roots, decimal numbers, matrices, functions, infinity. He points out, for example, that the fundamental theory of calculus must be understood from two complementary perspectives (each of which was discovered independently), as differential calculus and as integral calculus.

How far do we take the TA process? Clearly, at some point, we must stop looking for new interpretations in order to pursue more practical matters. A limitation of this paper is that I do not address this question. Nor do I address exactly how the TA process might be modelled or nurtured. I suggest only that short-sighted interpretations of TA and of ET appear insufficient. Sensitivity to novel interpretations might yield richer rewards.

This research is limited also by challenges in circumscribing and writing about complex phenomena, including non-intellectual processes (e.g., cognition, biology, culture). It is impossible to refer to non-intellectual processes without first intellectualizing them. Intellectualizing a process makes it available for discourse; however, this does not imply that the process itself is an intellectual process. For example, writing about an experience is not the same as the experience itself: the experience exists whether or not the experience is intellectualized. Additionally, the process of intellectualization can serve as an obstacle to experience. Well-documented cognitive biases (including confirmation bias and availability bias) suggest that beliefs and values can distort our picture of reality. In other words, once a process is intellectualized, its idea may get in the way of other interpretations.

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## Appendix A

Table 3. *Technology Focus of ERIC Articles Related to ET*

| | Article | Focus |
|---|---|---|
| 1. | Bit by Bit or All at Once? Splitting up the Inquiry Task to Promote Children's Scientific Reasoning | S |
| 2. | Cognitive Load Theory, the Transient Information Effect and E-Learning | S |
| 3. | A Study about Using Internet in History Lessons | H |
| 4. | Wikipedia as a Teaching Tool for Technological Pedagogical Content Knowledge (TPCK) Development in Pre-Service History Teacher Education | H |
| 5. | Enhancing Interpretation of Natural Phenomena through a Mathematical Apparatus: A Proposal of an Interactive Unit in Optics | S |
| 6. | Using Dynamic Geometry Software GeoGebra in Developing Countries: A Case Study of Impressions of Mathematics Teachers in Nepal | H |
| 7. | Laptop Usage Affects Abstract Reasoning of Children in the Developing World | H |
| 8. | Using Wiki in Teacher Education: Impact on Knowledge Management Processes and Student Satisfaction | H |
| 9. | Learning in a u-Museum: Developing a Context-Aware Ubiquitous Learning Environment | H |
| 10. | Effect of Answer Format and Review Method on College Students' Learning | S |
| 11. | Is a Schools' Performance Related to Technical Change?--A Study on the Relationship between Innovations and Secondary School Productivity | S |
| 12. | An Investigation of Mobile Learning Readiness in Higher Education Based on the Theory of Planned Behavior | H |
| 13. | The Implementation of E-Tutoring in Secondary Schools: A Diffusion Study | H |
| 14. | Using ICT for School Purposes: Is There a Student-School Disconnect? | H |

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| 15. | The Role of Scaffolding and Motivation in CSCL | S |
| 16. | Can We Teach Digital Natives Digital Literacy? | H |
| 17. | The Verbal Facilitation Effect in Learning to Tie Nautical Knots | S |
| 18. | How Should the Higher Education Workforce Adapt to Advancements in Technology for Teaching and Learning? | H |
| 19. | Shared and Personal Learning Spaces: Challenges for Pedagogical Design | H |
| 20. | Leveraging New Media Skills in a Peer Feedback Tool | H |
| 21. | Multimodal Design, Learning and Cultures of Recognition | S |
| 22. | Soundwalks, Community, and the Secondary General Classroom | H |
| 23. | ICT in ELT: How Did We Get Here and Where Are We Going? | H |
| 24. | Engaging Students in Higher Education through Mobile Learning: Lessons Learnt in a Chinese Entrepreneurship Course | H |
| 25. | Understanding Preservice Teachers' Technology Use through TPACK Framework | H |
| 26. | The Impact of Collaborative and Individualized Student Response System Strategies on Learner Motivation, Metacognition, and Knowledge Transfer | S |
| 27. | How Artefacts Mediate Small-Group Co-Creation Activities in a Mobile-Assisted Seamless Language Learning Environment? | H |
| 28. | Preparing Pre-Service Teachers to Integrate Technology in Education: A Synthesis of Qualitative Evidence | H |
| 29. | Researching Haptics in Higher Education: The Complexity of Developing Haptics Virtual Learning Systems and Evaluating Its Impact on Students' Learning | H |
| 30. | Invisible Success: Problems with the Grand Technological Innovation in Higher Education | ? |
| 31. | Learning in the Early Years: Social Interactions around Picturebooks, Puzzles and Digital Technologies | H |
| 32. | Using Digital Technologies to Redress Inequities for English Language Learners in the English Speaking Mathematics Classroom | H |
| 33. | Scaffolding Information Problem Solving in Web-Based Collaborative Inquiry Learning | H |
| 34. | Preschool Children's Learning with Technology at Home | H |

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| 35. | Operation ARA: A Computerized Learning Game that Teaches Critical Thinking and Scientific Reasoning | H |
| 36. | Higher Education Scholars' Participation and Practices on Twitter | H |
| 37. | Detecting Breakdowns in Local Coherence in the Writing of Chinese English Learners | H |
| 38. | On the Design of Online Synchronous Assessments in a Synchronous Cyber Classroom | H |
| 39. | Measuring Flow Experience in an Immersive Virtual Environment for Collaborative Learning | H |
| 40. | Understanding Mobile Learning from the Perspective of Self-Regulated Learning | H |
| 41. | One Mouse per Child: Interpersonal Computer for Individual Arithmetic Practice | H |
| 42. | Using a Wiki in a Scientist-Teacher Professional Learning Community: Impact on Teacher Perception Changes | H |
| 43. | Using the Cognitive Apprenticeship Web-Based Argumentation System to Improve Argumentation Instruction | H |
| 44. | Using Blogs and New Media in Academic Practice: Potential Roles in Research, Teaching, Learning, and Extension | H |
| 45. | "My School, My University, My Country, My World, My Google, Myself"...What Is Education for Now? | H |
| 46. | Learning to Listen and Listening to Learn: One Student's Experience of Small Group Collaborative Learning | S |
| 47. | Using Multimedia Tools to Support Teacher Candidates' Learning | H |
| 48. | Prevalence and Correlates of Screen-Based Media Use among Youths with Autism Spectrum Disorders | H |
| 49. | Utopian Universities: A Technicist's Dream | H |
| 50. | The Corrosive Influence of Competition, Growth, and Accountability on Institutions of Higher Education | S |
| 51. | Constructing a Deconstructed Campus: Instructional Design as Vital Bricks and Mortar | H |
| 52. | A Reaction to Mazoue's Deconstructed Campus | H |
| 53. | The Durability of Professional and Sociomathematical Norms Intentionally Fostered in an Early Pedagogy Course | S |

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| 54. | Developing a Pedagogical-Technical Framework to Improve Creative Writing | H |
| 55. | A New Approach to Personalization: Integrating E-Learning and M-Learning | H |
| 56. | Fostering Personalized Learning in Science Inquiry Supported by Mobile Technologies | H |
| 57. | Development of a Personalized Educational Computer Game Based on Students' Learning Styles | H |
| 58. | Modelling Diffusion of a Personalized Learning Framework | S |
| 59. | Empowering Personalized Learning with an Interactive E-Book Learning System for Elementary School Students | H |
| 60. | Experiencing Indigenous Knowledge Online as a Community Narrative | H |
| 61. | The Impact of Nintendo Wii to Physical Education Students' Balance Compared to the Traditional Approaches | H |
| 62. | The Impact of Technology-Enabled Active Learning (TEAL) Implementation on Student Learning and Teachers' Teaching in a High School Context | H |
| 63. | Explaining the Segmentation Effect in Learning from Animations: The Role of Pausing and Temporal Cueing | S |
| 64. | Making Games in the Classroom: Benefits and Gender Concerns | S |
| 65. | Preparation versus Practice: How Do Teacher Education Programs and Practicing Teachers Align in Their Use of Technology to Support Teaching and Learning? | H |
| 66. | ICT-Integrated Education and National Innovation Systems in the Gulf Cooperation Council (GCC) Countries | H |
| 67. | Building Virtual Cities, Inspiring Intelligent Citizens: Digital Games for Developing Students' Problem Solving and Learning Motivation | H |
| 68. | Teacher Beliefs and Technology Integration Practices: A Critical Relationship | H |
| 69. | What Factors Predict Undergraduate Students' Use of Technology for Learning? A Case from Hong Kong | H |
| 70. | Online Help-Seeking in Communities of Practice: Modeling the Acceptance of Conceptual Artifacts | H |
| 71. | Challenge of Supporting Vocational Learning: Empowering | H |

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| | Collaboration in a Scripted 3D Game--How Does Teachers' Real-Time Orchestration Make a Difference? | |
| 72. | Exploring the TPACK of Taiwanese Elementary Mathematics and Science Teachers with Respect to Use of Interactive Whiteboards | H |
| 73. | Using Online Collaboration Applications for Group Assignments: The Interplay between Design and Human Characteristics | H |
| 74. | Development of a Moodle Course for Schoolchildren's Table Tennis Learning Based on Competence Motivation Theory: Its Effectiveness in Comparison to Traditional Training Method | H |
| 75. | Slide Presentations as Speech Suppressors: When and Why Learners Miss Oral Information | H |
| 76. | Promoting and Scaffolding Argumentation through Reflective Asynchronous Discussions | H |
| 77. | Educational Interface Agents as Social Models to Influence Learner Achievement, Attitude and Retention of Learning | H |
| 78. | Evaluating the Use of Problem-Based Video Podcasts to Teach Mathematics in Higher Education | H |
| 79. | Digital Storytelling for Enhancing Student Academic Achievement, Critical Thinking, and Learning Motivation: A Year-Long Experimental Study | H |
| 80. | Implementing Web 2.0 Technologies in Higher Education: A Collective Case Study | H |
| 81. | Enhancing 5th Graders' Science Content Knowledge and Self-Efficacy through Game-Based Learning | H |
| 82. | Tweens' Characterization of Digital Technologies | H |
| 83. | Review of Trends from Mobile Learning Studies: A Meta-Analysis | H |
| 84. | Learning Basic Surgical Skills through Simulator Training | H |
| 85. | Using Virtual Microscopy to Scaffold Learning of Pathology: A Naturalistic Experiment on the Role of Visual and Conceptual Cues | H |
| 86. | 4SPPIces: A Case Study of Factors in a Scripted Collaborative-Learning Blended Course across Spatial Locations | H |
| 87. | Context Matters: The Value of Analyzing Human Factors within Educational Contexts as a Way of Informing Technology-Related Decisions within Design Research | S |
| 88. | Comments on "Reflections on 'A Review of Trends in Serious | H |

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| | Gaming'" | |
| 89. | Using Computer-Based Continuing Professional Education of Training Staff to Develop Small- and Medium-Sized Enterprises in Thailand | H |
| 90. | Mobile Practices in Everyday Life: Popular Digital Technologies and Schooling Revisited | H |
| 91. | Facebook as a Learning Tool? A Case Study on the Appropriation of Social Network Sites from Mobile Phones in Developing Countries | H |
| 92. | The Five Central Psychological Challenges Facing Effective Mobile Learning | H |
| 93. | Questioning the Character and Significance of Convergence between Social Network and Professional Practices in Teacher Education | H |
| 94. | Tweeting for Learning: A Critical Analysis of Research on Microblogging in Education Published in 2008-2011 | H |
| 95. | Assistive Technology and Students with High-Incidence Disabilities: Understanding the Relationship through the NLTS2 | H |
| 96. | Online People Tagging: Social (Mobile) Network(ing) Services and Work-Based Learning | H |
| 97. | Museum Learning via Social and Mobile Technologies: (How) Can Online Interactions Enhance the Visitor Experience? | H |
| 98, | Exploring the Use of the iPad for Literacy Learning | H |
| 99. | Accommodating Band Students with Visual Impairments | S |
| 100. | The Influence of Video Analysis on the Process of Teacher Change | S |
| 101. | Can Motivation Normalize Working Memory and Task Persistence in Children with Attention-Deficit/Hyperactivity Disorder? The Effects of Money and Computer-Gaming | S |
| 102. | How Music Technology Can Make Sound and Music Worlds Accessible to Student Composers in Further Education Colleges | H |
| 103. | Effects on Learners' Performance of Using Selected and Open Network Resources in a Problem-Based Learning Activity | H |
| 104. | Watching, Creating and Achieving: Creative Technologies as a Conduit for Learning in the Early Years | H |
| 105. | Analyzing the Latent Emotional Transfer Pattern (LETP) of a Learning Community in an Online Peer-Assessment Activity | H |
| 106. | Understanding Factors Associated with Teacher-Directed Student Use | H |

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| | of Technology in Elementary Classrooms: A Structural Equation Modeling Approach | |
| 107. | Effects of Game Technology on Elementary Student Learning in Mathematics | H |
| 108. | PGDnet: A New Problem-Solving Virtual Learning Environment | H |
| 109. | University Students' Behavioral Intention to Use Mobile Learning: Evaluating the Technology Acceptance Model | H |
| 110. | The Fast-Paced iPad Revolution: Can Educators Stay up to Date and Relevant about These Ubiquitous Devices? | H |
| 111. | Message Design for Mobile Learning: Learning Theories, Human Cognition and Design Principles | S |
| 112. | Professional Learning during a One-to-One Laptop Innovation | H |
| 113. | How Learning in an Inverted Classroom Influences Cooperation, Innovation and Task Orientation | H |
| 114. | Technology-Supported Learning Environments in Science Classrooms in India | H |
| 115. | Leveraging the Affordances of YouTube: The Role of Pedagogical Knowledge and Mental Models of Technology Functions for Lesson Planning with Technology | H |
| 116. | Monitoring Student Progress Using Virtual Appliances: A Case Study | H |
| 117. | A Hybrid Approach to Develop an Analytical Model for Enhancing the Service Quality of E-Learning | H |
| 118. | Computer Games in Pre-School Settings: Didactical Challenges when Commercial Educational Computer Games Are Implemented in Kindergartens | H |
| 119. | Do Challenge, Task Experience or Computer Familiarity Influence the Learning of Historical Chronology from Virtual Environments in 8-9 Year Old Children? | H |
| 120. | The Acceptance of Moodle Technology by Business Administration Students | H |
| 121. | Teachers' Pedagogical Beliefs and Their Use of Digital Media in Classrooms: Sharpening the Focus of the "Will, Skill, Tool" Model and Integrating Teachers' Constructivist Orientations | H |
| 122. | Promoting Vicarious Learning of Physics Using Deep Questions with Explanations | H |

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| 123. | Which Social Elements Are Visible in Virtual Groups? Addressing the Categorization of Social Expressions | S |
| 124. | Key Instructional Design Issues in a Cellular Phone-Based Mobile Learning Project | H |
| 125. | Learning through Online Peer Discourse: Structural Equation Modeling Points to the Role of Discourse Activities in Individual Understanding | H |
| 126. | A Pilot Study of Cooperative Programming Learning Behavior and Its Relationship with Students' Learning Performance | H |
| 127. | Using Synchronous Peer Tutoring System to Promote Elementary Students' Learning in Mathematics | H |
| 128. | Implementing Computer-Based Assessment--A Web-Based Mock Examination Changes Attitudes | H |
| 129. | To Use or Not to Use: Psychometric Properties of the Willingness to Use Technology (WUT) Instrument in Three Asian Contexts | H |
| 130. | Teachers' Acceptance and Use of an Educational Portal | H |
| 131. | Development and Evaluation of a Web 2.0 Annotation System as a Learning Tool in an E-Learning Environment | H |
| 132. | Differential Impact of Unguided versus Guided Use of a Multimedia Introduction to Equine Obstetrics in Veterinary Education | H |
| 133. | Technology-Supported Performance-Based Feedback for Early Intervention Home Visiting | H |
| 134. | The Integration of Personal Learning Environments & Open Network Learning Environments | H |
| 135. | Behavior Breakthroughs[TM]: Future Teachers Reflect on a Focused Game Designed to Teach ABA Techniques | H |
| 136. | A Breakthrough for Josh: How Use of an iPad Facilitated Reading Improvement | H |
| 137. | Engaging Pre-Service Science Teachers to Act as Active Designers of Technology Integration: A MAGDAIRE Framework | H |
| 138. | Tribes, Territories and Threshold Concepts: Educational Materialisms at Work in Higher Education | ? |
| 139. | Applause as an Achievement-Based Reward during a Computerised Self-Assessment Test | H |
| 140. | Voice over Instant Messaging as a Tool for Enhancing the Oral | H |

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| | Proficiency and Motivation of English-as-a-Foreign-Language Learners | |
| 141. | System Dynamics in Medical Education: A Tool for Life | S |
| 142. | Through Efficient Use of LORs: Prospective Teachers' Views on Operational Aspects of Learning Object Repositories | H |
| 143. | Student Use of Animated Pedagogical Agents in a Middle School Science Inquiry Program | H |
| 144. | The Layering of Mathematical Interpretations through Digital Media | H |
| 145. | Investigating the Feasibility of Using Digital Representations of Work for Performance Assessment in Engineering | H |
| 146. | School-Based ICT Policy Plans in Primary Education: Elements, Typologies and Underlying Processes | H |
| 147. | Assessing Scientific and Technological Enquiry Skills at Age 11 Using the E-Scape System | H |
| 148. | Assessment Is for Learning: Supporting Feedback | H |
| 149. | False Reality or Hidden Messages: Reading Graphs Obtained in Computerized Biological Experiments | H |
| 150. | Memorization Effects of Pronunciation and Stroke Order Animation in Digital Flashcards | H |
| 151. | Collaboration or Cooperation? Analyzing Group Dynamics and Revision Processes in Wikis | H |
| 152. | CALL Evaluation: Students' Perception and Use of LoMasTv | H |
| 153. | Web 2.0 and Second Language Learning: What Does the Research Tell Us? | H |
| 154. | Using Video Social Stories[TM] to Increase Task Engagement for Middle School Students with Autism Spectrum Disorders | H |
| 155. | Critical Pedagogic Analysis: An Alternative to User Feedback for (Re)Designing Distance Learning Materials for Language Teachers? | S |
| 156. | Transnational Private Authority in Education Policy in Jordan and South Africa: The Case of Microsoft Corporation | H |
| 157. | A Community of Voices: Educational Blog Management Strategies and Tools | H |
| 158. | Enhancing Instruction through Constructivism, Cooperative Learning, and Cloud Computing | H |

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| 159. | A Tale of Three Cities: Review of the Development of ICT in School Education between Hong Kong, Macau and Singapore | H |
| 160. | Lessons Learned: A "Homeless Shelter Intervention" by a Medical Student | H |
| 161. | Risks, Rewards, and Responsibilities of Using New Literacies in Middle Grades | H |
| 162. | From Knowledge to Wisdom: Critical Evaluation in New Literacy Instruction | H |
| 163. | Our Compulsory Goals: Effective Teaching and Meaningful Learning through Powerful Cultural Tools | S |
| 164. | Middle Schools and New Literacies: Looking Back and Moving Forward | S |
| 165. | Writing Teachers Should Comment on Facebook Walls | H |
| 166. | Blog-Enhanced ICT Courses: Examining Their Effects on Prospective Teachers' ICT Competencies and Perceptions | H |
| 167. | Exploring the Educational Potential of Robotics in Schools: A Systematic Review | H |
| 168. | An Attitude Scale for Smart Board Use in Education: Validity and Reliability Studies | H |
| 169. | The Development, Validity and Reliability of TPACK-Deep: A Technological Pedagogical Content Knowledge Scale | H |
| 170. | The Effect of Computer-Assisted Teaching on Remedying Misconceptions: The Case of the Subject "Probability" | H |
| 171. | Using Blogs to Support Learning during Internship | H |
| 172. | Situating ICT in the Teacher Education Program: Overcoming Challenges, Fulfilling Expectations | H |
| 173. | Assessing the Effects of Interactive Blogging on Student Attitudes towards Peer Interaction, Learning Motivation, and Academic Achievements | H |
| 174. | Supporting Collaboration with Technology: Does Shared Cognition Lead to Co-Regulation in Medicine? | H |
| 175. | The Effects of Achievement Goals and Self-Regulated Learning Behaviors on Reading Comprehension in Technology-Enhanced Learning Environments | H |
| 176. | Integrating Computer-Supported Collaborative Learning into the | H |

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| | Classroom: The Anatomy of a Failure | |
| 177. | Key Factors to Instructors' Satisfaction of Learning Management Systems in Blended Learning | H |
| 178. | Cheating Behaviours, the Internet and Education Undergraduate Students | H |
| 179. | Examining Mobile Learning Trends 2003-2008: A Categorical Meta-Trend Analysis Using Text Mining Techniques | H |
| 180. | Online versus Paper Evaluations: Differences in Both Quantitative and Qualitative Data | H |
| 181. | Adopting Webcasts over Time: The Influence of Perceptions and Attitudes | H |
| 182. | FODEM: A Multi-Threaded Research and Development Method for Educational Technology | H |
| 183. | Learners' Perceptions and Illusions of Adaptivity in Computer-Based Learning Environments | H |
| 184. | Investigating the Influences of a LEAPS Model on Preservice Teachers' Problem Solving, Metacognition, and Motivation in an Educational Technology Course | H |
| 185. | Challenges in Assessing the Development of Writing Ability: Theories, Constructs and Methods | S |
| 186. | Utilising Podcasts for Learning and Teaching: A Review and Ways Forward for E-Learning Cultures | H |
| 187. | When "Teaching a Class of Daemons, Dragons and Trainee Teachers"--Learning the Pedagogy of the Virtual Classroom | H |
| 188. | How Simulation/Gaming Transformed My Life | S |
| 189. | Innovation Diffusion: Assessment of Strategies within the Diffusion Simulation Game | H |
| 190. | Life Span as the Measure of Performance and Learning in a Business Gaming Simulation | H |
| 191. | Music Improvisation and Composition in the General Music Curriculum | S |
| 192. | Music Technology and Musical Creativity: Making Connections | H |
| 193. | Multidimensional Vector Model of Stimulus-Response Compatibility | S |
| 194. | Calculus in Elementary School: An Example of ICT-Based Curriculum Transformation | S |

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| 195. | Making Sense of Integer Arithmetic: The Effect of Using Virtual Manipulatives on Students' Representational Fluency | S |
| 196. | Assistive Technology and Mathematics Education: Reports from the Field | H |
| 197. | Does Clicker Technology Improve Student Learning? | H |
| 198. | Multimedia Design Principles in the Psychomotor Domain: The Effect of Multimedia and Spatial Contiguity on Students' Learning of Basic Life Support with Task Cards | H |
| 199. | Multimedia Design Principles in the Psychomotor Domain: The Effect of Multimedia and Spatial Contiguity on Students' Learning of Basic Life Support with Task Cards | H |
| 200. | Video Production and Classroom Instruction: Bridging the Academies and the Realities of Practice in Teacher Education | S |

*Note.* This table contains a sample of 200 peer-reviewed journal articles published in 2012 and indexed in the ERIC DB[29]. I reviewed the abstracts and descriptors for each of these articles, searching for indicators of what each researcher means by the term "technology". In reference to "technology", the majority of researchers (80%) refer to hard technology (resources such as hardware or software); they do not use the term technology in reference to soft technology (such as learning processes).
The final column in the table indicates their apparent technological focus:

- "H" represents an apparent "hard technology" focus, where the term "technology" appears to refer to hardware or software
- "S" represents an apparent "soft technology" focus, where the term "technology" appears to refer to processes

[29] I used the following search criteria on 2012-10-07: Thesaurus Descriptors:"Educational Technology" and Publication Type:"Journal Articles" and Peer Reviewed and Publication Date:2012-2012