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Knowledge in Technology Education

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Edited by Howard Middleton

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CONTENT

Foreword

The issue of what constitutes knowledge in technology education is the overarching theme for TERC2010. What is useful or powerful knowledge in technology education and why is that so and how do we know that?

In 2000 the International Technology Education Association launched its publication *Standards for Technological Literacy: Content for the Study of Technology* and concluded that it represented what every person should know and be able to do in order to be technologically literate. More recently the connections between technology, innovation design and engineering (TIDE) have been highlighted and even more recently the connections between science, technology, engineering and mathematics (STEM). _All of these have implications for the nature of technological knowledge.

Contributors to the proceedings come from America, Australia, Canada, England, Hong Kong, Ireland, Israel, Japan, Malaysia, New Zealand, South Africa, Sweden The Netherlands, Taiwan and the USA. The chapters cover a wide range of contemporary issues and themes in technology education including, curriculum, cognition, pedagogy, primary technology, teacher education, contentious issues, information and communication technologies. As with previous conferences many papers could not be classified into single categories and displayed rich interconnections between a number of issues. What is both important and heartening to see is the range of research projects being undertaken to improve the quality of technology education.

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Convenor, TERC 2010

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Technology Education: Towards a Conceptualisation of Higher-Order Thinking

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It has become an important aim of technology education learning activities to support students use and development of higher-order thinking. However, it seems that current theories have difficulties with defining higher-order thinking, and this lack of understanding often results in technology education teaching and learning that is fashioned by teacher intuition rather than by knowledge gained through empirical research. In other words, experienced technology educators are well versed in the teaching of technology related content, however they are provided with minimal support in understanding the nature of and support for higher-order thinking in their classrooms. In response to this disparity in knowledge, this paper briefly reviews relevant literature to underpin the need to establish a conceptualisation of higher-order thinking. Subsequent to this review, higher-order thinking is conceptualised in terms of cognitive, behaviour setting and activity theories.

Introduction

Inspiration for this paper is drawn from a study that examines theories of cognition, behaviour settings and activity in order to interpret the technology education learning environment in terms of its capacity to promote student higher-order thinking (Walmsley, 2009). The following sections of this paper provide a partial synopsis of the literature review from within that study.

Teaching and Learning in Technology Education

Technology education is moving towards a curriculum more focused on technological problem-solving. For example, Sanders (2001) studied the transition from industrial arts to technology education within a number of American education districts. Sander's collection of survey responses from 418 teachers within these various districts indicated that a transition towards technology education was evident. In response to the results of his study, Sanders argues that:

> Considerable change has been taking place over the past few decades, but the legacy of industrial arts is also evident throughout the data. The dynamic between change and legacy seems to characterize the field at this point in time; technology education is a work-in-progress.
>
> (Sanders, 2001, p. 53)

Zuga (2004) and Zuga and Bjorkquist (1989) argue that the movement towards technology education and away from industrial arts education has resulted in a research effort focused on curriculum content and to a lesser extent on instructional methods that support such learning objectives as problem-solving, innovation and higher-order thinking. Therefore, curriculum change, as highlighted by Sanders' (2001) study, indicates that research should focus more on examining the pedagogy (i.e. instructional design or teaching strategy selection), in addition to the content of contemporary technology

education classrooms.

DeMiranda (2004) argues that exemplary contemporary technology education classrooms display teaching strategies that reflect cognitive or intellectual theories of learning and that the learning environments in these classrooms support student higher-order thinking. Conversely, Schultz, (1999) argues that technology education classrooms that base their curriculum on the more traditional project work have the potential to support student higher-order thinking. While it is important to understand how student higher-order thinking might be supported within the various forms of technology education classrooms, it would seem equally as important to understand the nature of higher-order thinking in order to do so. The following section briefly reviews literature that examines the nature of and contemporary definitions for higher-order thinking.

Contemporary Understandings of Higher-Order Thinking

Resnick (1990, 1987) argues that across educational stakeholders there are various definitions for higher-order thinking. Resnick argues further that the various thinking skills (e.g. critical thinking, metacognition, cognitive strategies, heuristics etc.) advanced by those who appear to hold different theoretical orientations are in fact related. More recently, Smith (2001) argues that attempts to define higher-order thinking in terms of these aforementioned skills have proven untenable.

Lewis and Smith conclude that philosophers lean towards critical thinking as a focus for instruction: *while psychologists prefer the term thinking skills* (Lewis & Smith, 1993, p. 136). Smith (2001) argues that many theorists provide critical thinking as an alternative to higher-order thinking. Additionally, Smith argues that too often, critical thinking is defined as broadly encompassing all the thinking skills, rather than only those of: *reasoning and argumentation* (Smith, 2001, p.349). O'Tuel and Bullard agree that critical thinking as a term is sometimes regarded as including all forms of thinking: *hard or deeply* (O'Tuel & Bullard, 1993, p.1).

Bloom, Englehart, Furst, Hill and Krathwohl (1956) conceptualise a taxonomy of educational objectives. These objectives include knowledge, comprehension, application, analysis, synthesis, and evaluation. Postlethwaite, (1993) argues that Bloom et al's, (1956) taxonomy (i.e. Bloom's Taxonomy) is able to distinguish between cognitive demand at the lower and higher levels, with knowledge or recall being at the lower and evaluation being at the higher end of the continuum. The levels of analysis, synthesis and evaluation are often represented in the literature as being indicative of thinking at the higher-order levels (Cruikshank & Olander, 2002; O'Tuel & Bullard, 1993). Thus, there appears to be a view that thinking is hierarchical, but different views about how thinking at the higher end of the hierarchy is conceptualised.

Cuban argues that attempts to define different forms of thinking (e.g. critical thinking, problem-solving, creative thinking, metacognition, etc.) have proven to be a: *conceptual swamp* (Cuban, 1984, p.676). That is, difficulties with defining different forms of thinking have arisen because of the inherent desire of researchers and stakeholders to segregate philosophical and psychological constructs. In other words, the sciences (i.e. psychology) most often utilise a scientific problem-solving approach, while the humanities (i.e. philosophy) consistently utilise a critical evaluative approach to the solving of problems

(Lewis & Smith, 1993). However, Lewis and Smith (1993), Newmann (1990) and Smith (2001) argue that a more general framework is required to interpret the processes of thinking. Lewis and Smith (1993) and Smith (2001) argue that current approaches to the study of thinking have been defined in terms of an overly narrow focus on specific thinking skills, such as critical thinking. On this basis, Cuban (1984), Lewis and Smith (1993), Newmann (1990) and Smith (2001) argue for a definition of higher-order thinking that transcends disciplinary boundaries.

Conceptualising Higher-order Thinking

Walmsley (2009) utilised quantitative and qualitative research methods to examine students' interactions with different types of learning activity within the technology education classroom setting in terms of students' higher-order thinking outcomes. The study from which this paper is drawn (Walmsley, 2009), advances a conceptualisation of higher-order thinking, synthesised to incorporate influence from the behaviour setting, culturally mediated activity (i.e. actions using culturally significant technical and psychological tools), and the hierarchically controlled internal cognitive structures of a person. The synthesis of these theories (i.e. cognitive theory, behaviour setting theory and activity theory), as conceptualised in terms of higher-order thinking, infers meaning to classroom activity, classroom actions and teachers' decisions made relative to prescribed classroom learning outcomes and students' use of higher-order thinking in the realisation of these outcomes (i.e. the object of the activity system) within technology education classes. The following sections of this paper provide theoretical support for the concept of higher-order thinking as advanced in Walmsley's (2009) study of student higher-order thinking within technology education classrooms.

Hierarchy of Cognitive Structures

Lewis and Smith argue that there exists a: *general agreement that lower and higher order thinking skills can be distinguished* (Lewis & Smith, 1993, p.132). Stevenson (1984) advances a theory of cognitive adaptation that conceives of the cognitive system as consisting of cognitive items (facts or conceptual knowledge) and procedures (procedural knowledge) at varying levels or orders. Stevenson combines aspects of Anderson's (1982) theory of skill acquisition, Scandura's (1981) hierarchy of rules and Fischer's (1980) skill theory to formulate a theory of adaptive cognitive processes which traces the acquisition and development of cognitive skills through a hierarchy of transformations (Stevenson, 1986a, 1986b; Stevenson & Evans, 1994; Stevenson, 1998). That is, cognitive items are transformed by higher-order procedures into specific lower-order procedures during initial learning. These lower-order procedures are then combined or restructured by general-purpose (higher-order) procedures during subsequent learning situations. Anderson argues that: *the basic control architecture across these situations is hierarchical, goal structured, and basically organized for problem solving* (Anderson, 1982, p.403).

Barkley (2001) provides a model of covert adaptive cognitive processes which is hierarchically organised in a similar fashion to Stevenson's (1984) theory of cognitive adaptation. Stevenson's (1984) and Barkley's (2001) theories of cognitive adaptation are congruent to the extent that they identify a broadly applicable hierarchical cognitive system that enables transformations to occur. Despite each theory originating from different

perspectives, with Stevenson's emanating from cognitive psychology and Barkley's emanating from neuropsychology, it is argued that the two theories can be interpreted as being mutually supportive in terms of acknowledging a hierarchically structured cognitive system that has as its purpose for the individual to adapt to new and unusual circumstances. However, understanding the controlling mechanism that helps people to decide when to do what is an issue that arises when higher-order thinking is examined. Therefore, the following section examines literature regarding self-regulation and higher-order thinking.

Self-Regulation

The self-regulated learner has a requirement for competence, autonomy and relatedness (Stefanou, et al, 2004) and has personal attributes (thinking dispositions or thoughtfulness) that facilitate meaningful engagement with the learning situation. Ryan and Deci (2000) argue that it is the satisfaction of an individual's basic need for self-regulation that contributes to a feeling of psychological wellbeing and it is essential for educators, employers, etc. to acknowledge situations that promote the fulfilment of these self-regulatory needs. Boekaerts defines self-regulation as:

> ...students' attempts to attain personal goals by systematically generating thoughts, actions, and feelings at the point of use, taking into account the local conditions. Self-regulation is a "fundamental psychological construct".
> (Boekaerts, 2002, p.602)

According to Boekaerts (2002), adaptation to non-routine situations is governed by a person's goals (i.e. desirable hypothetical futures) and is regulated by a person's theory of self (i.e. a person's prior learning or life memories). *Both experience and context contribute to SRL* [self-regulated learning] (Paris, & Paris, 2001, p.99). Therefore, it is argued that higher-order thinking is governed by a process of self-regulation. That is, a person's goals or hypothetical futures promotes and regulates a person's higher-order thinking processes towards satisfactory goal attainment. In other words, self regulation and goal attainment (i.e. a person's perception of a desirable hypothetical future for oneself) drive the process of higher-order thinking by determining when the goal has and has not been achieved.

Additionally, students are influenced by aspects of the learning environment (Stevenson, 1986a). These aspects or factors affect the level of cognitive engagement that students exhibit with their learning tasks (Talbert & McLaughlin, 1993; Tessmer & Richey, 1997). Stevenson (1986a) defines the influence or press on student thinking by particular factors within the learning environment as Cognitive Holding Power. Cognitive Holding Power (CHP) is defined as the press exerted by an educational learning environment, which causes students to execute certain levels of procedural knowledge (Stevenson, 1986a), that is, to engage students in particular kinds of thinking. Press in this context refers to the learning environments' influence on positive or negative goal attainment and is activated by the tasks students are required to encounter within the educational environment (Stevenson, 1986a, 1998). Students perceive and interpret these tasks based on their own internal cognitive structures and on the proximal influence or Cognitive Holding Power of the task environment (Stevenson & Evans, 1994). In other words, the environment influences the perception of a person in terms of goal attainment and thus has an influence on the processes involved in higher-order thinking. The following section examines literature concerned with the learning environment and higher-order thinking.

The Learning Environment

Barker's (1968, 1978) theory of behaviour settings is examined to conceptualise the environment's influence on an individual's process of cognitive adaptation. Chiel and Beer argue that:

> Adaptive behaviour is the result of continuous interaction between the nervous system, the body and the environment, each of which have rich, complicated, highly structured dynamics.
> (Chiel & Beer, 1997, p.555)

The premise of Barker's theory is that the behaviours of the majority of people within a setting can be predicted because of the influence of the characteristics of that setting. In other words, the setting exhibits a causal effect upon collective individual behaviour and this effect occurs irrespective of the innate differences between individuals within the same setting (Barker, 1968, 1978; Wicker, 1984, 1991, 2002). Behaviour setting theory acknowledges the interaction of person and place, for without people a place cannot be defined as a behaviour setting (Barker, 1978; Wicker, 1984).

Behaviour settings contain human and non-human components, have spatial and temporal boundaries and have ongoing patterns of behaviour, or programs that govern how the majority of human participants engage in their activities (interactions between people and inanimate objects) while they inhabit the setting (Wicker, 1984). Behaviour settings are self-regulating to the extent that they support the desirable hypothetical futures (personal goals) of individuals and these individuals strive to maintain the program in order to realise these goals (Wicker, 1984). However, it is not imperative that all members of a behaviour setting have exactly the same goals; though it is imperative that the aggregation of these disparate goals maintains the setting program. Therefore, behaviour settings may be conceptualised as a complex system of relationships between objects and behaviours that support and maintain individual goal attainment through a socially maintained setting program.

While behaviour setting theory uses the behaviour setting as its unit of analysis, activity theory uses the: historically evolving collective activity system, seen in its network relations to other activity systems, ...as the prime unit of analysis against which scripted strings of goal-directed actions and automatic operations are interpreted (Engeström, 2000, p.960). Therefore, because of its focus on collective activity as the basis for the meaningfulness of individual actions, the following section examines literature related to the role of activity within settings and its influence on higher-order thinking.

Activity Theory

The central principle of activity theory is that human cognition exists because of the interrelationship between the individual and his or her socially determined material environment (Susi & Ziemke, 2001). The activities of the individual are: *motivated and regulated by higher-order goals and are realised through actions that are themselves relatively independent components of each activity* (Hacker, 2001, p.58). Jonassen and Rohrer-Murphy argue that: *...activity theory provides us with an alternative way of viewing human thinking and activity* (Jonassen & Rohrer-Murphy, 1999, p.62). Rather than learning occurring as a precursor to activity, activity theory proposes that learning occurs simultaneously within activities (Roth, 2004).

Susi and Ziemke (2001), Hacker (2001), Engeström (2000) and Jonassen and Rohrer-Murphy, (1999) argue that within activity theory, activities are considered to have a

hierarchical structure. At the highest level, activities are undertaken as a result of a personally significant motivating factor. This motivating factor or overall collective purpose is defined as the object of the activity. *The object of the activity affects the nature of the activity, which affects the object in a dynamic relationship* (Jonassen & Rohrer-Murphy, 1999, p. 65). That is, transformations occur which have a reciprocal influence on the object of the activity and the activity itself (Susi & Ziemke 2001; Jonassen & Rohrer-Murphy, 1999). Subordinate actions are directed at more specific intermediate goals and it is the aggregation of these actions that support the activity and thus overall collective achievement purposes. Individual goals would not make sense without the collective object of the activity system. That is, an activity system (i.e. the aggregation of goal-directed actions and automatic operations) can only be fully understood when interpreted against the overall object of the activity.

Conclusion: A Conceptualisation of Higher-Order Thinking

The literature associated with cognition, behaviour settings and activity systems provides some justification for the concept that cognition involves a hierarchical, controlled, adaptive system that facilitates cognitive transformations. These transformations result from engagement with non-routine situations when a person's memories of previous experiences prove to be inadequate in pursuit of personally relevant goals or possible hypothetical futures. Stevenson's (1984) and Barkley's (2001) theories are mutually supportive in this regard. Self-regulation has been outlined as an important facilitator of higher-orders of thinking. Behaviour setting theory (Barker, 1968, 1978) supports a view of behaviour settings as having an ordered and socially maintained program that impacts, both negatively and positively, upon various individuals' personal goal attainment from within that setting, and thus influences the types of activities a person may engage in during routine or non-routine situations in pursuit of their goals. Activity theory provides a dynamic framework for analysing actions as part of collective activities in context, and acknowledging the role of culture and history during goal attainment.

Therefore, it would appear that the reviewed literature is related in important ways. That is, cognitive theory argues that higher-order thinking has a hierarchical structure and is self-regulated to support goal attainment. Behaviour setting theory argues that behaviour settings are bounded, self-regulated and maintain a setting program in order to support goal attainment. Activity theory argues that activity regulates and is regulated by the collective object of the activity, and that the object is the motivating factor that regulates individual actions in pursuit of goals. Thus, the self-regulated attainment of personally important goals provides a point of intersection and focus between and within these theories.

Current theories seem to relate higher-order thinking mainly with individuals and focus on heuristics or the conditions of use of higher-order thinking, rather than on a holistic interpretation of the nature of higher-order thinking and how learning and the environment can be structured in its support. Therefore, it may be argued that higher-order thinking, as conceptualised (Walmsley, 2009), empowers influence upon both the individual and the environment. This relationship is significant, because it recognises that higher-order thinking does not originate solely in the individual and that higher-order

thinking is influenced by other factors. Importantly for technology education, it is argued that some of these factors can be controlled and modified by the teacher (Walmsley, 2009).

Acknowledgement

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