Journal of Technology Education

Current Editor: Chris Merrill, cpmerri@ilstu.edu
Previous Editors: Mark Sanders 1989-1997; James LaPorte: 1997-2010

Fall 2005 **Volume 17, Number 1**

Creativity—A Framework for the Design/Problem Solving Discourse in Technology Education

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Subjects for which aesthetics and creative performance are critical curricular dimensions (such as art, physical education, music, and technology education), and which are accommodative of students across the range of intelligences (Gardner, 1999) are not readily or completely captured by content standards. Therefore content knowledge in these fields that target student achievement as conventionally conceived must be complemented by treatment of more subjective and elusive goals such as the development of connoisseurship, appreciation, or creative insight. With the publication of standards for the subject (International Technology Education Association, 2000), the need for focus upon creativity in technology education has been made more urgent than before because of the prominence given to the teaching and learning of design. Four of the standards (8, 9, 10, and 11) address design directly. Technological design is a medium through which dimensions of children's creative abilities can be stimulated and augmented. This creative potential of design teaching can be seen in the work of Druin & Fast (2002), where Swedish children who are included in the design of technology reveal inventive dispositions in their journaling. It can be seen also in the work of Foster and Wright, 2001; Gustafson, Rowell and Guilbert, 2000; Neumann, 2003; and Parkinson, 2001.

Arguably, stimulating creative impulses in children through design and problem-solving activities is as grand a goal of curriculum as is the achievement of particular design-based, measurable outcomes. But how do we get children to improve upon the quality of their designs? What makes one design solution more elegant than the other? There are no easy answers here because creativity does not quite respond to the accustomed inquiry questions that we pose in discussion of curriculum, instruction and assessment questions in technology education. As Bruner (1962) pointed out, creativity is a silent process which by its very nature will not be responsive to the processes ordinarily employed to determine content standards. Instead, it requires its own set of questions, including examination of its nature.

This article seeks to stimulate a conversation about the inculcation of creativity as an important goal of technology education, and as a concomitant of the goals of the Standards for Technological Literacy. The purpose is to direct the attention of the field to an area of the subject that remains under-explored. It could be argued that creativity underpins the substantial attention that has been devoted within recent times to design and problem solving. But much of this attention is implicit rather than explicit. There is a need for design and problem solving in technology education to be framed not so much in terms of methodologies of engineers, but as opportunities for students to step outside of conventional reasoning processes imposed by the rest of the curriculum. Creativity has compelling claims to being the anchoring idea in such a framework.

Should a conversation on the creative dimension of technology education blossom to the full, the result could be the unearthing of issues and challenges that could become the basis of a framework for research (see Lewis, 1999) and for re-consideration of technology-based curriculum and instruction. A creativity focus augments the content standards thrust by causing us to be preoccupied not just with student learning of technological concepts and processes, but with what children can learn about themselves by engaging technology. The article unfolds by addressing (a) what is creativity, (b) creative cognitive processes, (c) schooling and creativity, (d) creativity and technology education, and (e) implications for technology education.

What is Creativity?

Creativity is not easily defined, because of its unseen character. As Boden (1994) points out, inventors often do not know the source of their insight. Still, it is possible to discern the creative from the ordinary. Bailin (1994) notes that while there has not been universal agreement on what constitutes creativity, there are shared beliefs about its nature, as follows (a) that creativity is connected with originality—with a break from the usual (b) that the value of creative products cannot be objectively ascertained, since there are no standards by which new creations can be assessed (c) that beyond products, creativity can be manifested in new and novel ways of thinking that break with previously established norms (d) that existing conceptual frameworks and knowledge schema impose restraints on creative insight, and (e) that creativity is a transcendent, irreducible quality.

An enduring definition provided by Bruner (1962), is that creativity is an act that produces “effective surprise” p. 3. Bruner explained that the surprise associated with creative accomplishment often has the quality of obviousness after the fact. The creative product or process makes perfect sense—once it is revealed. For the creative person, surprise, according to Bruner, “is the privilege only of prepared minds—minds with structured expectancies and interests” p. 4. Bruner identified three kinds of surprise, *predictive* (such as in theory formulation or re-formulation), *formal* (as in a musical composition where there is an elegant reordering of elements), and *metaphorical* (as in the idea of “systems”), where the creativity comes from recognizing commonality across disparate elements.

Tardif and Sternberg (1988) suggested that it could be fruitful to dissect creativity into processes, persons, and products, and indeed, much of the research on creativity is framed along these lines. Creative processes take time, and include search through a problem space. They may involve transformations of the external word, internal representations through analogies and metaphors, constant definition and re-definition of problems, applying recurring themes, and recognizing patterns. Creative people are governed by internal factors, especially personality. They invariably are creative within particular domains, such as art, music, or electronics. But across domains creative people share common cognitive characteristics such as the ability to think metaphorically and flexibly, the ability to recognize good problems in their fields, and the willingness to take intellectual risks.

Composite Nature of Creativity

A view of creativity around which there has been a growing consensus that it is a composite concept, the product not just of individual traits, but also of societal and environmental factors. Csikszentmihalyi (1988) offered such a view, having proposed that creativity is never accomplished by an individual alone, but rather is the product of the interaction of a stable cultural *domain* that will ensure perpetuation of the idea, a supporting institutional framework (a *field*) comprised of the stakeholders and gatekeepers who affect the structure of the domain, and an *embedded social system*. By this way of thinking, attributions of what is creative are relative, and grounded in social agreement. Lubart (1995) wrote that to be creative is to produce work that is both novel and socially useful, and that the less parochial is the context of the accomplishment, the more highly creative is the work.

Creativity and Intelligence

Whether creativity correlates with or is completely explained by theories of intelligence has been a point of issue. The consensus appears to be that creative behavior has to be explained outside of the framework of intelligence. And indeed, Gardner (1999) has proposed that intelligence resides in a multiplicity of human attributes. In a seminal piece, Guilford (1950) suggested that to fathom creativity one had to look beyond the normal boundaries of IQ. He contended that creativity was not confined to geniuses, but rather, on the principle of *continuity*, it was present albeit in varying degrees, in all humans.

Feldhusen (1993) wrote that creativity has readying and predisposing conditions, one being intelligence, but that while intelligence is an asset, it is not a sufficient condition for creative behavior. Sternberg (1985; 1988) has contended that creativity overlaps with intelligence, cognitive style, and personality/motivation, and that it has socio-cultural as well as experiential correlates. While the intellectual dimension of creativity deals with problem finding, problem definition and redefinition, and knowledge acquisition, personality aspects govern traits such as tolerance for ambiguity and willingness to surmount obstacles.

Theories of Creativity

Several strands of theory support inquiry into creativity. Busse and Mansfield (1980) suggested seven lines, namely, psychoanalytic, Gestalt, associationism, perceptual, humanistic, cognitive developmental, and composite theories (such as Koestler's (1969) *bisociation*). Houtz (1994) condensed these lines into four approaches, namely (a) associationism/behaviorism—connection among disparate ideas, and between stimulus and response (especially Mednick, 1962), (b) psychodynamic, focused on conscious and unconscious thought (thus inclusive of the psychoanalytic), (c) humanism, focused on intra-individual life forces and motivations, and (d) cognitivism, focused on thinking processes and skills. These two categorizations clearly intersect. They provide frameworks for inquiry into creativity, and a backdrop for understanding creative processes.

Creative Cognitive Processes

Just what are the cognitive processes that yield creative ends? One approach to resolution here is to examine the logic of exceptionally creative people. In one such study, Cross (2002) used phenomenological methods to explore the creative cognitive processes of three exceptional designers from different domains of design, and found some commonality in their approaches including (1) they relied on first principles both in origination and development of concepts (such as adherence to fundamental physical principles or design basics), (2) they explored the problem space in a way that pre-structures or foreshadows the emergence of design (for example, they may give precedence to providing joy to the user), and (3) creative design comes about when there is tension to be resolved between problem goals and solution criteria. Using these areas of commonality, Cross fashioned a model suggesting that exceptional designers take a broad systems approach to design, but they also frame problems in distinctive personal ways that seem to issue from their particular personalities.

Also examining the approach of exceptionally creative people, Csikszentmihalyi (1996) arrived at his conception of *flow*, the optimal state of experience that yields novelty and discovery. From his observation he too arrived at a systems explanation, surmising that creative flow involves feedback that produces enjoyment when novelty occurs. When things are going well in the act of creating, subjects report their behavior to be almost automatic and unconscious. This state of flow seems to be preconditioned by a set of enablers including having clear goals, balancing between challenges and skill, merging action and awareness, and not fearing failure.

While much could be learned about creative processes through examination of the logic of people who are exceptionally creative, it needs to be remembered that creative behavior is not monopolized by the gifted (Guilford, 1950). For example, Chomsky (1957) called attention to the routine, flexible use of language among humans. Ward, Smith and Finke, (1999) contended that human ability to construct an array of concepts from otherwise discrete experiences is evidence of our "generative ability." Generative ability includes cognitive acts such as retrieval of existing structures from memory, forming simple associations, transforming existing structures into new ones, analogical transfer, and metaphorical thinking. Such abilities, along with conceptual combination, divergent thinking, and productive thinking, are processes that must become better understood in the technology education community as modes of reasoning associated with creative production. Next, these cognitive processes identified here are briefly examined.

Metaphorical Thinking.

Metaphors are powerful creative tools that allow comparison and categorization of materially unlike entities. They involve mapping across conceptual domains, from a source domain to a target domain (Glucksberg, Manfredi & McGlone, 1997; Lakoff, 1993). An example of metaphorical thinking would be the characterization of the Internet as an "information highway." By facilitating description of new situations through reference to familiar ones, metaphors allow conceptual leaps (e.g., Glucksberg & Keysar, 1990). Metaphors bring into play the right side of the brain, which, different from the logically oriented left side, is holistically oriented, supportive more of the strategic than the tactical, and can facilitate dealing with ambiguity. They function at the executive level, subsuming analogies, and relying on the principle of association to facilitate connections among unlike entities (e.g., Genter & Jeziorski, 1993; Sanders & Sanders, 1984).

Metaphorical thinking exercises can be employed as auxiliary activities supportive of design teaching and learning in technology education. Teachers can provide students with prototypic examples of metaphors, then require them to conceive of as many as they can.

Analogical Thinking

An analogy is a special type of metaphor, its signature being a structural match between two domains (Gentner, Brem, Ferguson, Wolff, Markman, & Forbus, 1997). Analogical thinking involves mapping of knowledge from a base domain to target domain to facilitate one-to-one correspondence. An example would be the connection that Rutherford made between the solar system and the hydrogen atom (Gentner & Jeziorski, 1993), or the parallelism that can be drawn between electric current flow and fluid flow. Analogies are tactical; they make possible the solution of a given problem by superimposing upon it the solution to a problem in a different domain (e.g., Gick & Holyoak, 1980). Thus, airplane flight is analogous to the flight of birds. The spider-web has been the basis of design of architectural structure.

Analogical thinking can conceivably aid design reasoning in technology education classrooms, if teachers are able to draw upon particular technological examples where the inspiration for the design came from nature. Students can readily see the similarity between airplanes and birds. They can learn about the stability of structures by studying the foundation of trees. If they are encouraged to conceive of many more such analogical examples, students will thereby be engaging in the kind of thinking that is required for solving design puzzles.

Combinatorial Creation

Combinatorial creation is a design process in which two or more concepts or entities are combined to yield an entirely new product (Wisniewski, 1997). It is a creative approach explainable by association or composite theories. In nature the combination of hydrogen and oxygen yields water, a unique product with properties different from the component gases (Ward, Smith, & Vaid, 1997). In the commercial world, the combination of two dissimilar products can yield a composite novel result. For example, metals are made more resilient by alloying. A kite combined with water skis provide a novel recreational vehicle. Seeing the novel combinatorial possibilities inherent in two dissimilar objects requires creative insight, and uncovering how people reason about combinations can be a way to gain understanding of the nature of creativity.

In the technology education classroom, combinatorial activities could become part of the repertoire of the teacher. Students could be asked to arrive at designs that are the product of two existing objects or products. They can be given thought exercises, the aim of which could be to imagine new products that can materialize from combinations of existing ones.

Divergent Thinking

Divergent thinking was included by Guilford (1959) as a facet of his structure of intellect. In this work, Guilford proposed that intellect was composed of thought processes or *operations, contents* that are the raw material of operations, and *products* that are outcomes of operations. Divergent thinking and convergent thinking were included among operations. Convergent thinking yields fully determined conclusions drawn from given information. It is associated with general intelligence. *Divergent thinking yields a variety of solutions to a given problem.* Guilford (1967) found divergent thinking to be composed of four factors, *fluency*, ability to produce many ideas; *flexibility*, producing a wide variety of ideas; *originality*, producing novel ideas; and *elaboration*, adding value to existing ideas. Divergent thinking is believed to be a characteristic of creative minds (e.g., Baer, 1993; Wakefield, 1992). In technology education it squares with approaches to the teaching of design that require students to brainstorm and to generate multiple solutions to problems.

Productive Thinking

Productive thinking is creative behavior as characterized by Gestalt theorists. Wertheimer (1968) applied it to problem solving, suggesting that structural features of the problem set up stresses in the solver, and that as these stresses are followed up they cause the solver to change his/her perception of the problem. The problem is restructured, peripheral features are separated from core features, and solutions emerge. Duncker (1945) suggested that the act of problem solving involves reformulating the problem more productively. The problem solver must invent a new way to solve the problem by redefining the goals and approaching the final solution incrementally via a succession of insights. He found that *insight* occurs in problem solving only when the solver is able to overcome a mental block, especially that induced by prior knowledge. If the solver thinks of using an object only in the habitual way, where a novel approach is required, creativity will be blocked. He referred to this experienceinduced impediment to creativity as “functional fixedness.” If one is accustomed to seeing a box used as a container, one may have difficulty seeing the same box as a platform (see Mayer, 1995).

Productive thinking in the technology education classroom would require students to restate or restructure problems in ways that make it easier for them to begin to see solution prospects. As students deconstruct problems, discarding aspects that are not germane to the solution, they are drawn closer to solutions. Students could be provided “thinking outside the box” exercises that require them to consider multiple uses to which everyday objects or devices can be put.

Schooling and Creativity

Schooling is an important aspect of the development of creativity in children. Support for such development can begin with a curriculum that takes student interest and individual differences, including thinking styles, (Sternberg, 1990) into account. Especially, the curriculum must account for the multiple intelligences among students (Gardner, 1999). We can gain insight into what creativity enhancement through the school curriculum might entail by setting forth the six resources identified by Lubart and Sternberg (1995) as being critical to creative performance as a framework. These “resources” are (1) problem definition or redefinition, (2) knowledge, (3) intellectual styles, (4) creative personality, (5) motivation to use intellectual processes, and (6) environmental context. How can these resources be engaged in classrooms?

While students with exceptional creative talent would benefit from curricula that deliberately include a creativity-oriented component, all children stand to benefit when such an approach is taken. Cropley (1997) contended that the inculcation of creativity should be a normal goal of schooling, with the aim being to help all students attain their creative potential. Children should be helped to achieve effective surprise in their work. He outlines a framework of ideas around which a creativity-focused curriculum can revolve—one that overlaps with Lubart and Sternberg's resources approach. It includes provision of content knowledge, encouraging risk taking, building intrinsic motivation, stimulating interest, building confidence, and stimulating curiosity (Cropley, p. 93). As can be seen here, creativity enhancement must address factors that are *internal* to the student, such as personality and intellectual disposition, as well as factors that are *external*, such as curricular, social, and environmental.

Domain knowledge features are a key prerequisite of creative productivity in the schemas offered by both Lubart and Sternberg (1995) and Cropley (1997) . There is strong evidence in the research literature indicating that a fund of domain knowledge is imperative for creative accomplishment (e.g., Simonton, 1988; Csikszentmihalyi, 1996). Cropley (1997) contended that providing such knowledge is one important way in which schools can foster the development of creativity. Lubart and Sternberg (1995) write that knowledge of the state of knowledge in a domain prevents attempts to reinvent the wheel. Nickerson (1999) offered the view that the importance of domain-specific knowledge in the forging of creativity is underestimated. He argued that across a wide front of domains, including the arts, mathematics, and science, acquisition of a solid knowledge base is a precursor of exemplary creativity. He wrote:

> One cannot expect to make an impact in science as a consequence of new insights unless one has a thorough understanding of what is already known, or believed to be true, in a given field. The great innovators of science have invariably been thoroughly familiar with the science of their day. Serendipity is widely acknowledged to have played a significant role in many scientific discoveries; but it is also acknowledged that good fortune will be useful only to one who knows to recognize it for what it is. (p.409)

It is necessary to offer a caveat with respect to the importance of domain knowledge and it is the contention that prior knowledge could sometimes impede creative behavior. As Lubart and Sternberg (1995) pointed out, high levels of knowledge can actually stymie creativity. Dunker (1945) referred to this possibility of the problem of "functional fixedness" where one is unable to break away from normative usage of an item. Weisberg (1999) spoke of the tension between knowledge and creativity, suggesting a U-relationship between the two that acknowledges both positive and negative transfer of knowledge. Still, the fact that prior experience or knowledge could conceivably depress creativity is more a caution than an argument against domain-knowledge acquisition as a basis of expertise and creativity. Schools must provide children with the foundational knowledge supportive of creative insight.

Beyond provision of domain knowledge, schools can enhance the creativity of children if classroom environments support and facilitate risk taking, problem posing, individual learning and thinking styles, and intrinsic and extrinsic motivation (Jones, 1993; Jay & Perkins, 1997; Lubart & Sternberg, 1995; and Cropley, 1997). Some school contexts are more supportive of creative behavior than others, and the factors that can militate against creative behavior may be both internal and external in character (Jones, 1993). For example, low selfesteem could inhibit creative effort (e.g., Hennessey & Amabile, 1988). The external environment can dampen creativity if it does not reward creative behavior, or if it deliberately suppresses it.

Creativity can be enhanced in the curriculum by providing students more opportunity for problem finding, as a precursor to problem solving (e.g., Moore, 1993). Problem finding has not been given as much prominence in technology education as problem solving (see Lewis, Petrina, & Hill, 1998). France & Davies (2001) show how questions can be a part of a collaborative process in community-based problem solving. Wertheimer (1968) drew attention to the importance of problem-finding as a marker of creativity, contending that "Often in great discoveries the most important thing is that a question is found. Envisaging, putting the productive question is often more important, often a greater achievement than solution of a set question…" p.141. Problem finding refers to the way that a problem is conceived and posed, and includes the formulating of the problem statement, periodic assessment of the quality of the problem formulation and solution options, and periodic reformulation of the problem (e.g., Getzels & Csikszenthmihalyi, 1976; Jay & Perkins, 1997). Mumford, Reiter-Palmon and Redmond (1994) wrote that problem construction contributes to creative problem solving, and that it is a predictor of real world creativity. Runco and Chand (1994) examined how individuals decide whether problems are worth pursuing, finding that metacognitive evaluation is a key to their method.

Creativity and Technology Education

Technology education is a special place in the school curriculum where creativity can be fostered uniquely. Indeed, the subject is premised upon human creativity—on the ingenious ways in which from the time they stood upright, human beings have devised ways and means to deal with problems that beset them in daily existence to assure their very survival, and ultimately to improve the quality of their lives. In the long march across time from river crossings in canoes, to space crossings on rocket-powered ships, human beings have along the way systematically relied upon their creativity to overcome existential obstacles, and with each advance have yielded and stored technological knowledge upon which even further advance could be made.

Early forms of the subject tended to focus upon rehearsing basic overt technological processes, such as tool use, and the making of artifacts. As the subject has progressed, there has been a retreat from this essentially instrumental focus toward one where children are taken behind the scenes of human advancement and presented with hurdles that can be overcome only through their creative design. This shift of the subject to an earlier place in the stage of the process of technological creation, where things are unsettled and there is no single right answer, has made the subject almost ideally suited to uncovering dimensions of the creative potential of children that would remain hidden in much of the rest of the curriculum. While the American content standards in science now include technological design as an area of study (see National Research Council, 1996), the long tradition of technology education gives the latter subject a much greater claim to this content.

Design

The strong design focus of the American Standards for Technological Literacy offers opportunities for teaching to enhance creativity. What makes design so specially suited to the inculcation of creativity in children is its openendedness. There is more than one right answer, and more than one right method of arriving at the solution. The ill-structured character of design requires that students resort to divergent thought processes and away from the formulaic. As they do so, their creative abilities are enhanced. But despite the potential here, there are indications in the literature that we still have some way to go before creativity becomes a more central feature of the teaching of design in the United States and elsewhere. For example, McCormick and Davidson (1996) cautioned that in teaching design, British teachers were giving precedence to products over process. Others observe that technology teachers in Britain were pursuing a formulaic line when teaching design, comprised of stages that were often contrary to the natural design tendencies of children (e.g., Chidgey, 1994; Johnsey, 1995).

This tendency toward teaching design as a process that proceeds through definable stages is evident in the United States as well, noticeable in the Standards for Technological Literacy (International Technology Education Association, 2000), which states that:

> The modern engineering profession has a number of well developed methods for discovering such solutions, all of which share common traits. First, the designers set out to meet certain design criteria, in essence, what the design is supposed to do. Second, the designers must work under certain constraints, such as time, money, and resources. Finally the procedures or steps of the design process are iterative and can be performed in different sequences, depending upon the details of the design problem. (p. 90)

Reeder (2001) set forth a set of comparable steps in his description of how industrial design is taught at his university, but included is a conceptual development stage that involves open-ended, divergent thinking.

The problem for the field of technology education in the United States and elsewhere is that the overt description of the stages of the design process, observable when engineers do their work, has become the normative design pedagogy. This stage approach runs the risk of overly simplifying what underneath is a complex process. Teaching design as a linear stage process is akin to arriving at a pedagogy of art by mere narration of the observable routines of the artist. It simply misses the point that design, like art, proceeds from deep recesses of the human mind. To arrive at a pedagogy of design, there is need to get beneath the externals of the process. The key is to recognize design as a creative rather than a rationalistic enterprise.

Roger Bybee, a strong advocate of the new standards for technological literacy, wrote that "Technological design…involves cognitive abilities such as *creativity* (emphasis added), critical thinking, and the synthesis of different ideas from a variety of sources" (Bybee, 2003, p.26). This creative element requires an approach to teaching that gets deeper below the surface.

We are beginning to see interesting deviations from the normative approach to the teaching of design (e.g., Hill & Anning, 2001; Flowers, 2001; McRobbie, Stein & Ginns, 2001; Mawson, 2003; and Warner, 2003. One concept being explored is "designerly thinking" where a constructivist approach to student design approach is taken in an effort to unearth just how students solve problems. Flowers suggested that humor in the design and problem solving classroom can promote divergent thinking. Arthur Koestler (1969) gave credence to humor as an important marker of creativity in his landmark contribution, *The Act of Creation*. Humor in the creativity-oriented classroom is consistent with the view, embedded in leading theories and research, that creativity has an affective dimension—that it thrives in environments in which intrinsic motivation flourishes. Such environments encourage non-conformist thinking and personality types that thrive better in less structured settings (e.g., Eysenck, 1997).

Warner (2003) joins Flowers in pointing out that the tone of classrooms can make a difference in the quality of the creations of children. He argued that to support creativity in technology education classrooms, teachers must be more tolerant of failure. Flowers wrote that "Teachers of design must maintain a classroom culture that promotes successes but embraces the learning opportunities that failure presents" (p. 10). He drew on research suggesting that some kinds of classroom climates, such as those where competition is encouraged or where rewards are offered for performance, actually dampen creativity (e.g., Hennessey & Amabile, 1988).

Earlier in this article, generative cognitive processes such as analogical and metaphorical thinking, conceptual combination, productive thinking and divergent thinking were identified as means by which creative people have arrived at novel products. Such processes should be included in the pedagogic repertoire of technology teachers. They should be taught to students in design classes in technology education, as devices that can be employed in solving design challenges. We see an excellent example of the how metaphorical and analogical thinking can be infused into the teaching of design in the contribution by Reed (2004) on biomimicry; that is, design that imitates nature. Reed showed that many scientists and engineers continue to look to nature as they contemplate designs and that many industrial products (e.g., Velcro) are inspired by nature.

Design pedagogy can benefit from ideas such as biomimicry, as prompts for helping students as they engage in creative search. This pedagogy must also be informed by findings emerging from the creativity research literature, especially from studies in which expert designers articulate the logics that underpin decisions they make and actions they take in the act of designing (e.g., Cross, 2002).

Beyond cognitive strategies that are known to yield novel products are the concomitant factors that support creativity, notably the importance of domain knowledge, problem posing, and problem restructuring. We have learned from the literature that domain knowledge is fundamental to creative functioning (e.g., Cropley, 1997). And yet, this is an area of the design discourse in technology education that receives almost no attention. Creativity cannot proceed in a knowledge vacuum. While there is a place for the teaching of domain-independent design, where the context is everyday functional knowledge, it is necessary that children be challenged with design problems that reside in particular content domains, such as electronics, manufacturing, or transportation. Children are more likely to arrive at creative solutions when they puzzle over such problems if they are first taught the supporting content knowledge.

Though problem posing ability is an acknowledged marker of highly creative behavior (notably Getzels & Csikszenthmihalyi, 1976; and Wertheimer, 1968), it remains an almost neglected aspect of the technology education discourse—a discourse steeped in treatment of problem solving. And yet, as Lewis, Petrina & Hill (1998) argued, using principles of constructivist learning in support, that we should be as interested in the ability of children to find good problems as in their ability to solve problems. There are implications here for how we arrive at design problems in our classrooms. Are those problems teacher-imposed, or do they originate from the observations of our students? Akin (1994) called attention to the creative potential of problem restructuring for increasing the creative potential of design. Drawing from experiences in architecture he distinguishes between anonymous and signature design, and between routine and ill-defined problems. Ill-defined problems are not bounded by available design standards. They require "the additional functionality of problem restructuring as they cannot be resolved without a framework within which problem solving can operate" (p.18). According to Akin, within problem restructuring resides great creative potential, capable of yielding signature work. This view that problem restructuring engenders creativity is consistent with the concept of productive thinking (Duncker, 1945; Wertheimer, 1968).

There clearly is a need in technology education for a more textured discourse on the teaching of design than currently exists. Problem posing, problem restructuring, analogical and metaphorical thinking, and the use of humor are pedagogical devices that belong in an expanded view of how the creative aspect of design can be realized.

Implications for Technology Education

Unquestionably, the publishing of content standards represents an advance for technology education. This article has offered creativity as the framework for a discourse on design and problem-solving, and as a complementary conversation to that on content standards. In a way, this article constitutes a caution to the technology education community that the subject is still a work in progress, and that there are aspects of it that are not given naturally to rationalistic content-derivation methods. We are at a point where the subject in the curriculum from which technology education increasingly takes its cue is science, with its exactness; but it may be that we can benefit from alliances with other subjects, such as art or music, that have ill-structured aspects, and where students are encouraged to use knowledge not for its own sake, but in support of thought leading to creative expression.

Five kinds of implications for technology education are suggested by the discussion on creativity that has ensued here, namely (a) implications for design/problem solving pedagogy (b) implications for assessment (c) implications for professional development, (d) implications for curriculum theorizing, and (e) implications for research. Each is reflected upon briefly here as the article concludes.

Design/Problem Solving Pedagogy

Despite the centrality of design/problem solving activities to technology education, the field has not made strides in finding proven ways in which these activities can be taught. One explanation for lack of movement here is that insufficient attention has been paid to the role that creativity plays in design/problem-solving. A creativity focus allows for inclusion of a wider array of auxiliary activities into the pedagogic approach—activities in realms of divergent thinking, productive thinking, metaphorical thinking, analogical thinking, and combinatorial creations. Much more needs to be done in technology education to find approaches that are precursors of successful design experiences for children.

Assessment

As with pedagogy, assessment of design and problem-solving activities in technology education is still a fledgling area. A reason is that the field has not worked out measures for helping teachers determine the degree of creativity inherent in students' design-related work. When is the design routine, when middling, and when exemplary? This is an area of need. Technology education teachers have to be able to distinguish between gradations of creativity and to communicate their assessments to students in much the same way that teachers of art and music are able to do in their classrooms. There is a clear need here for an expanded discourse on assessment in the field that includes the challenges inherent in providing feedback to students when the intent is to help them improve their designs.

Professional Development

Pre-service teacher education programs in technology education ordinarily do not include coursework on creativity. Thus, most teachers do not have preparation that is sufficient enough to allow them to inject creativity into their teaching. Teachers may introduce design/problem solving activities into their teaching, but the competence they bring to the classroom is more in the realm of the technical than the aesthetic. There is a clear need here for professional development activities aimed at helping teachers see possibilities for introducing creative elements into the curriculum, and into instruction.

Curriculum

In the rich literature on technology education curriculum, creativity is often implicitly included, especially where the focus is on design and problem solving. But there is an absence of explicit treatment of the topic. This clearly is a shortcoming, made more telling by the new focus in the standards, on design. Creativity in all of its facets, and as it relates to technology education teaching and learning, needs to be a more deliberate focus of the technology education curriculum literature.

Research

Creativity has strong claims toward being a foundational area of research in technology education. Such research can address a host of pressing needs, including methods of assessing creative performance, auxiliary instructional activities that are good precursors of student creative performance, professional development activities that improve teacher competence in teaching design/problem solving, and strategies employed by students as they complete creative tasks.

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