Middle School Children's Thinking in Technology Education: A Review of Literature

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We began a project to understand what happens in middle school technology education classrooms in 2006 (Sanders, Sherman, Carlson, Kwon, 2007) in order to document the goals that technology education teachers pursue, the instructional strategies they use to teach children to meet these outcomes, the measures they use to assess achievement of these goals, and the learning actions that they believe students must engage to master their goals. We chose to focus on middle school because it is the school age when most children are introduced to organized, formal technology education curricula. In addition, middle school is often considered the time to begin focusing on influencing thinking with goals such as "teaching problem solving" (Sanders, 2001; Sanders, Sherman, Carlson, & Kwon, 2006). We believe it is important to understand middle school children's thinking in order to develop appropriate curriculum, to organize and deliver effective teaching, and to ensure that the goals established by the profession are pursued within the developmental abilities of middle school age children. Of course, understanding how children of all ages think and how they learn to use their intellectual abilities well is important. Our choice to limit our initial investigations to middle school was based on the idea that this is an especially fecund developmental period that may be a gateway for many students to begin developing the sophisticated thinking associated with problem solving and to decide to pursue further studies in technology education.

As part of this project, we identified and reviewed articles appearing in four technology education journals from 1995-2006 — Journal of Technology Education, Journal of Technology Studies, Journal of Industrial Teacher Education, and the International Journal of Technology and Design Education — that addressed middle school age teaching and students' thinking/learning. In

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this report, we present our review of articles appearing in these four journals that addressed middle school children's thinking. The review is divided into four sections: The first section summarizes investigations of middle school children's
problem solving/design, the second summarizes reports on gender issues, the third addresses laboratory/teaching context, and the final section reviews other issues raised in these journals relating to middle school children's thinking.

Middle School Children's Problem Solving Processes

Eight studies (Barak & Maymon, 1998; Lavonen, Meisalo, & Lattu, 2002; Jones, 1997; Michael, 2001; Mioduser & Kipperman, 2002; Twyford & Jarvinen, 2000; Welch, 1998; Welch & Lim, 2000) investigated aspects of the intellectual processes in which middle school children engage when addressing problem solving or design assignments in technology education. Five studies (Jones, 1997; Mioduser & Kipperman, 2002; Twyford & Jarvinen, 2000; Welch, 1998; Welch & Lim, 2005) compared the ideal problem solving heuristic presented in technology education text books with the thinking processes middle school children actually use when given problem solving/design problems. Lavonen, Meisalo, & Lattu (2002) and Barak & Maymon (1998) focused on the extent to which children would collaborate/work as teams while problem solving. Michael, 2001 explored the impact of computers on creativity. One study (Michael, 2001) employed experimental methods; the others are based on various qualitative approaches. Five studies appear to have well established reliability (Lavonen, Meisalo, & Lattu, 2002; Michael, 2001; Mioduser & Kipperman, 2002; Welch, 1998; Welch & Lim, 2000) by providing independent validity data while others (Barak & Maymon, 1998; Jones, 1997, Twyford & Jarvinen, 2000) leave the issue of reliability unclear. This section is divided into two parts: the first part addresses the studies that compared the ideal or text book problem solving heuristic with children's actual intellectual processes (Jones, 1997; Mioduser & Kipperman, 2002; Twyford & Jarvinen, 2000; Welch, 1998; Welch & Lim, 20005). The second part addresses the remaining studies (Barak & Maymon, 1998; Lavonen, Meisalo, & Lattu, 2002; Michael, 2001).

Middle School Children's "Natural" Problem Solving Thinking Processes

The central focus of these five studies (Jones, 1997; Mioduser & Kipperman, 2002; Twyford & Jarvinen, 2000; Welch, 1998; Welch & Lim, 20005) was the extent to which middle school children's untutored problem solving thinking mirrors the ideal process recommended in technology education text books. These studies emphasize the intellectual processes that children employ rather than physical or manual skills. Data for these studies were gathered by observing children as they worked on assigned problem solving/design tasks by asking children to think aloud and by interviewing them following the completion of the task or the time allocated for the task expired. The contexts for these studies were relatively unstructured in terms of how the students worked on their tasks. However, all the problem solving/design tasks included constraints such as time allowed to complete the task, the type of task the children were given, and materials available to complete the task. All students appeared to have been enrolled in at least some technology education classes prior to participating in these studies.

One consistent finding from studies of children's natural or untutored problem solving (Mioduser & Kipperman, 2002; Welch, 1998; Welch & Lim, 2000) was that students do not follow the ideal process presented in technology education text books. Nonetheless, middle school children did generate solutions using sophisticated intellectual skills following a build-test-revise-test-revise routine until reaching a solution or running out of time. This finding appears to hold if students are working in groups (Welch, 1998; Welch & Lim, 2000) or alone (Mioduser & Kipperman, 2002), and if given a short time frame of one or two hours (Welch, 1998; Welch & Lim, 2000), or a longer time ((Mioduser & Kipperman, 2002). The main contrast between the ideal and the actual processes children employed is the lack of preparatory planning and the types of models they sometimes built. Jones (1997) also found that middle school children generally did not plan and tended to act first. Untutored students appear to define their understanding of the relationship between the task, their skills, the available materials, and the time allotted by building what they initially believe to be the end product. Depending on what they produce, they shift their criteria of success and revise the product. This appears to be an "understanding by doing" (Twyford & Jarvinen, 2000) problem solving process which is complex and dynamic and in contrast to the ways the official process is portrayed in text books.

The ideal process may be counterproductive as a teaching strategy. Mioduser and Kipperman (2002) pointed out that most texts emphasize the steps in the ideal process to the extent that "…little room is left…for reflection, formative evaluation and resourceful decision-making beyond the detailed guidelines prescribed in a range of teaching materials" (p.124). They also questioned the efficacy of teaching the theoretical model while ignoring the "intellectual toolbox" (p. 134) necessary to implement the text book process. Because, there is scant evidence that experts follow the theoretical problem solving process proposed in technology education text books, further concerns emerged about presenting it to children as a guide for their problem solving. Rather than a sequence of stages characteristic of the commonly used text book prescriptive process, Mioduser and Kipperman (2002) suggested a functional approach (Mioduser, 1998) that defines an interconnected set of intellectual actions to develop problem solving/design solutions (identify, define, explore, implement, evaluate) that is more consistent with middle school age children's prior knowledge and natural tendencies. Welch and Lim (2000) and Twyford and Jarvinen (2000) echoed the idea of following students natural approaches because the "do-test-refine-test-refine" loop "…appeared to increase students' understanding of the problem" (Welch and Lim, 2000, p. 42) they were presented. In other words, the prior knowledge learners bring with them about how to solve problems "…clearly guide analysis and are a part of their interaction with peers." (Twyford and Jarvinen, 2000, p. 45). Thus, prior knowledge can be a powerful foundation to connect novice problem solving skills with progressively more sophisticated intellectual and operational strategies. Welch (1998) observed that "…the bulk of students' untutored technological problem-solving skills will have been acquired in the natural world: building sand castles, using commercial construction kits, constructing with found materials, and so on" (p. 254). Presenting a theoretical ideal problem solving routine that is alien to middle school children's experiences may be so unauthentic that students view it only as an esoteric exercise singularly useful to meet teachers' assigned artificial tasks.

Some evidence indicates that students will do as they have been taught in response to problem solving assignments regardless of the utility or benefits of following the text book model of problem solving. As a result, it is likely that routines such as following the theoretical problem solving model in the textbook will not transfer beyond the particular classrooms in which they are taught. For example, Jones (1997) noted that students are influenced by the culture of their classrooms. When their instruction focuses on building models, models become their "product" rather than the object the model represents. Barak and Maymon (1998) observed that students "…worked continuously and without time constraints, staying behind to work during recesses and after school hours (p. 11)" to complete an assigned project that was similar to the expectations they were required to meet during the whole school year. Finally, Atkinson (2000) observed, "In order to receive high marks teachers have encouraged pupils to provide evidence of each stage of the assessed process, whether it was appropriate to the efficient design of an artifact or not" (p. 260). It may be more productive to let young students follow their noses in terms of process and for teachers to focus more on promoting genuine thinking skills such as evaluating and revising. Over time, middle school children may learn more elaborate processes by imitating teachers as they present repetitive process modeling and multiple trials with projects. Questions such as, "How could this be better? What were you thinking when you decided to do this? What ways did you change your design as you built it and why? and, Can you think of different ways to think about what you did? may lead learners to consider not only what they do but the role of their intellectual skills as they engage in design/build learning.

These studies hint at two additional important issues. The first is the extent to which the ideal problem solving process is an accurate representation of the way problem solving/design is done by experts. The authors of the studies reviewed here portray the ideal problem solving/design process presented in technology education text books as a linear and uniform set of actions though there is virtually no evidence in the problem solving literature that supports the implied assumption that experts or novices, for that matter, ever think in this manner. Twyford and Jarvinen (2000) found that students may best learn to "do" technology by "doing" it. This includes recognizing that, "The pupil's mind changes and develops through active participation" (p. 45). Thus, it may be that the text book ideal conception of problem solving/design is inaccurate and should be abandoned as a teaching strategy. In contrast it may be more successful to focus on empirically verifiable intellectual skills, behaviors, and experiences typical of middle school children. Twyford and Jarvinen (2000) found that students vary widely in their experience, understanding, and vocabulary such that the same assignment will be interpreted in very different ways; focusing on "pragmatic" decision making and "constantly analyzing variables" (Twyford and Jarvinen, 2000, p. 45) may be more beneficial because all children are likely to have at least rudimentary abilities to engage these intellectual processes.

The second issue alluded to in these studies is the wisdom of teaching problem solving/design as a defined process, such as the text book heuristic, no matter how it is defined or portrayed. Because developmental theories offer little information and few strategies to teach specific intellectual routines, it may be preferable to provide middle school children with loosely structured opportunities to engage their design/build instincts and focus more on learners' intellectual actions than what they produce. After all, how realistic is it to expect or to teach middle school children to behave intellectually and/or physically like adult experts? For that matter, how realistic is it to find adults (teachers and others) who have the experiences and skills to behave in ways that are consistent with experts? Expertise gains its status by virtue of being unusual. Thus, expert problem solvers and the physical and intellectual processes they use may not provide the best model for teaching children the initial characteristics of problem solving and design.

Three additional observations are worth considering. First, in all of these studies, students appear to have been specifically chosen because they were enrolled in technology education classes or had demonstrated some skills or experiences that predicted they would be successful on the required assignments in the studies. Students in these studies were selected based on their experiences with similar projects, their advanced verbal abilities to work well in groups, or the probability they would be highly motivated. None of these studies involved students who were representative of the full range of abilities, interests, and prior knowledge that could be expected in public education middle school classrooms. Second, all of these studies limited the time available to students to complete the assigned projects; time available ranged from one hour to 24 hours total. These relatively short experiences may not provide sufficient time for expansive reflection, evaluation, or revision, the intellectual skills crucial for sophisticated problem solving even for middle school age children. Thus, it may be that the tasks and processes that children used in these studies are so constrained by time and the nature of the projects that they offer only the most tenuous implications for "normal" classrooms. Finally, one of the eight studies (Michael, 2001) was conducted in the United States indicating that generating implications for teaching problem solving/design in the United States should be done very cautiously. Some studies claimed that the children "enjoyed" the problem solving activity assigned; however, no evidence of enjoyment was presented other than the investigators' introspective interpretations of the children's behaviors.

These studies illustrate that middle school age children can solve problems using practical and sophisticated intellectual skills. It may be helpful to embed these thinking strategies in more authentic contexts that are realistic about the availability of material, the viability/appeal of the tasks, and the nature of support for resolving problems as children pursue solutions. That is, rather than present problem solving as a single well-defined linear routine, it may be more successful to teach problem solving as a messy, interactive, and ongoing series of situational decisions that focus at the same time on immediate design/build imperatives and the ultimate goals. Thus, making paper towers with an unlimited supply of paper, designing and building projects personally chosen, and having expert/teaching advice available for process and design/build questions may meld the advantages of learning by doing with doing for learning.

Other Issues Associated with Problem Solving

Three studies investigated the impact of computers on creativity (Michael, 2001) and teamwork behavior (Barak & Maymon, 1998; Lavonen, et al, 2002). Michael (2001) addressed the impact of computers to foster creativity in an experimental study; the results indicated that computers have no impact on creativity. Barak & Maymon, (1998) and Lavonen, et al (2002) provide little useful information on the emergence of teamwork "naturally." Incomplete descriptions make the report by Barak & Maymon (1998) problematic for generating reliable conclusions. The results from Lavonen, et. al (2002) indicated that middle school children appeared to be able to collaborate on computer programming problem solving tasks when specifically taught to engage in teamwork behaviors. In this study, students were taught to work in pairs to use proprietary programming software ("Empirica Interface, Empirica Control"). As is consistent with the findings reported above, these children did as they were taught; according to the authors, the software allowed them to engage in "physical thinking" (Lavonen, et al, 2002, p 152). These findings appear very limited in scope beyond the general conclusion that middle school children's thinking is unlikely to conform to the text book model of problem solving.

Gender

Studies by Weber & Custer (2005) and Silverman & Pritchard (1996) investigated the effects of gender on middle school children's preferences and choices in technology education using survey, observation, and interview methods. Though neither of these studies discovered many differences, females tended to prefer "designing" and males tended to prefer "utilizing" (Weber & Custer, 2005). Silverman & Pritchard (1996), though not uncovering gender based issues in middle school children's choices to pursue technology education beyond middle school, provided some perspective on three contextual issues that may be influential.

One of these contextual issues is the classroom environment in which gender stereotyping may have subtle impacts on females' decisions to pursue technology education. Classrooms may have a residue of discomfort that lurks below the surface but is still bothersome. A second issue is the apparent inability of at least some teachers to respond appropriately to control or counteract stereotypical behavior by males. Some teachers indicated they did not know how to respond to apparently minor provocations. A third issue may be the dynamics of interactions between males and females at middle school age. The teaching methods appear to be quite different in technology education versus other classes in that students are engaged in hands on activities; neither gender may have the experience to know how to appropriately behave under conditions where close and cooperative contact with peers is required.

Two studies investigated attitudes toward technology education in Hong Kong and Thailand using variations of the Pupils' Attitude Toward Technology (PATT) scale. Volk and Ming (1999) reported a number of gender based significant differences; however, these findings are problematic due to the use of multiple *t*-tests and the absence of power statistics. ANOVA analysis yielded a pattern that both male and female children who had more experiences and exposure to technologies were more likely to be interested in technology. Becker and Maunsaiyat (2002) conducted a validation study of a version of PATT for Thailand. The students used to validate the Thai version were "…lower secondary school students from one private school and three public schools in the Bangkok metropolitan area" (p. 11). They concluded that, "Overall, the patterns of attitudes and concepts of technology among US and Thai students were similar based on the results of this study" (p. 18). It may be that students' responses are a function of the questions asked more than the attitudes children hold or of location.

A contribution of these studies to understanding gender issues is to point to a need for more sophisticated investigations that clearly conceptualize differences based less on stereotypical preferences for types of projects or teaching methods and more on contextual factors and characteristics such as prior knowledge, learning goals, and motivation. One problem with these gender differentiation studies is that the conception of "technology" tends to be very traditional involving computers or some type of construction tool/machine. Thus, the differences observed, when they are observed, may be more oriented to particular types of technologies rather than toward technology as a concept. There may also be cultural differences that do not hold implications from one culture to another; these cultural differences may be between as well as within specific countries. One conclusion that appears to emerge from all of these studies is the importance of providing opportunities for children to experience a wide range of broadly based technology oriented intellectual and practical activities.

Laboratory Context

Three studies (Culbertson, Daugherty, & Merrill, 2004; Rogers, 2000; Weymer, 2002) investigated middle school children's response to different classroom/laboratory situations all of which included some aspects of curriculum delivered through a modular laboratory program. Weymer (2002) examined the impact of various personal characteristics on children's performance in modular technology education. He used a collection of existing data as well as several specific instruments to correlate students' "(a) prior knowledge of the MTE [modular technology curriculum] content, (b) verbal ability, (c) quantitative ability, (d) intrinsic motivation, and (e) cognitive style with regard to performance on a posttest instrument" (Weymer, 2002, p. 36). The modular technology unit taught "engineering structures" using "CAI" (computer assisted instruction). This study is problematic due to methodological flaws such as the involvement of the investigator with the participants, selection bias, and possible invalid use of instruments. The author's goal was to identify a profile of "how students' individual differences affect performance in MTE" (p. 42). Weymer (2002) concluded that "Students with low verbal ability, lacking prior knowledge, and preferring the field dependent cognitive style were especially at risk…" (p. 45).

Rogers (2000) examined the achievement differences between middle school children who were in "industrial technology education" in "traditional laboratory," "modular laboratory," and "contemporary laboratory" settings. Some unexplained methodological problems plague this study: different group sizes, lack of explanation of the instructional programs in the different settings, and inadequate school demographic information. Rogers (2002) found that the "contemporary laboratory instruction provided significantly better achievement than modular technology education in the areas of general industrial technology education knowledge, drafting technology, manufacturing processes, construction technology, and power/energy" (no page number) following a "nine-week industrial technology education course" (no page number).

Culbertson, Daugherty, & Merrill (2004) compared middle school (seventh and eighth grade) children's standardized test performance on reading, writing, arithmetic, mathematics, and reasoning following enrollment in one trimester, one-half trimester, or no enrollment in a modular technology education unit purported by the publisher to address these core skills (p. 13). The results "indicated that no significant difference existed between the achievement gains shown by each of the three groups in any of the five subject areas" (p. 17). Data were not collected to indicate student learning as a result of being enrolled in the technology education program.

One issue that emerges from these studies is possible confusion about the nature of modular programs. Two extreme views are that modular programs require little more than slavish adherence to directions (e.g. Pullias, 1997) and that modular programs provide opportunities for "self-sufficient" work (Shendow, 1996). While contributing little to resolving the efficacy of modular learning programs, these studies emphasize the possibilities that there may be unexamined consequences that are not necessarily meritorious from using modular programs. In addition, they raise questions as to the comparability of teacher lead and modular curricula particularly as technology education pursues outcome goals such as problem solving/design learning.

Other Investigations of Middle School Children

Three additional studies explored other middle school children issues in these journals. Schallies, Wellensiek, & Lembens (2002) attempted to create a developmental pattern of middle school children's understanding of technology and science in Germany. Using a questionnaire, they found that children's conceptions become somewhat more complex as they grow older; but, in general, the conceptions about technology and science of students of all ages are "not of sufficient clarity or depth," children tend to get their information about science from "media," and children demonstrate a "reductionist view of science and technology" (p 53-54). Because this research was carried out in southern Germany the findings may not be valid outside of Germany.

Boutin and Chenien (1998) and Chenien, Boutin, & Letteri (1997) reported on a program intended to teach Canadian middle school children to enhance their cognitive skills, self-esteem, academic performance, and attitudes toward school…" (no page number). The impact of the program was assessed by comparing dropout rates after two and one-half years. They report that the program resulted in decreased dropout rates and increased cognitive skills for students with high probability of dropout. Teachers reported that they were unprepared to teach these skills though they also reported that the training they received resulted in changing their teaching strategies. Technology education programs or students were not targeted in either study; thus, it is unclear if these results would apply specifically to children enrolled in technology education classes.

Conclusion

These studies raise important questions about influencing middle school children's thinking in technology education classrooms that should be pursued by technology education professionals. Among these questions are: Does teaching a defined heuristic as commonly appears in technology education text books promote or hinder children learning to solve problems? Does teaching a defined heuristic frustrate children using their prior knowledge to become more successful problem solvers? Can problem solving be more effectively taught and learned if instruction focuses on the intellectual skills needed to analyze, monitor, and revise than a defined heuristic? How can technology education teachers build on the prior knowledge children bring with them to teach specific intellectual skills that can be applied in tasks requiring sophisticated thinking such as problem solving/design? What intellectual skills do children need to learn and apply in order to develop problem solving strategies? Can all children learn and apply these problem solving/design skills and strategies?

In addition, it appears that the context in which technology education is taught may have an important impact on what and how children learn, another line of research that technology education professional should pursue. In particular, the role the teacher assumes may be critical in developing positive and supportive learning environments as well as in choosing and presenting content. While the evidence is modest, among the questions raised are: What is the impact of modular laboratory curriculum on children's intellectual skills and strategies? How can teachers promote positive interactions between all children in grouped assignments? Can technology education programs identify curricula that successfully stress learning intellectual skills?

Finally, these investigations illustrate the value of examining variables like children's thinking in technology education learning. Such investigations can be pursued both in classrooms and in more controlled circumstances. Of all the content included in technology education curricula, teaching children to use their intellectual abilities may be among the most important. These investigations indicate that much more knowledge is needed to develop a more complete picture of what and how to influence middle school children's intellectual processes.

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