Using Talking and Drawing to Design: Elementary Children Collaborating With University Industrial Design Students

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Study Purpose

In this study, Grade 3 (ages 8-9) children's talking and drawing were explored as they worked with university industrial design students to design and redesign drawings of a piece of furniture and produce a poster of their work. The researchers proposed that ideas about talking and drawing derived from interactions between children and the design students could be useful for discerning possibilities for children's classroom talking and drawing. The purpose of the study, therefore, was to provide insight into how talking and drawing could be used as tools for thinking about designs and how those insights could provide direction for teaching design technology in elementary classrooms.

Theoretical Framework

In recent years, much research has focused on how language contributes to learning (Hodson, 1998; Orsolini & Pontecorvo, 1992; Parker, 1992; Wells, 1995). Researchers describe language as being fundamental to children's knowledge construction and a tool for thinking (Hodson, 1998; Orsolini & Pontecorvo, 1992; Parker, 1992).

In design technology, talk is a verbal tool that children can use to develop ideas and communicate design thought. Discourse essentially involves the manifestation or expression of design ideas that allows children to take design ideas forward. Researchers have conducted classroom studies based on the belief that design technology is a social process in which learning is enhanced through talk that supports the construction of meaning about artifacts and devices (Anning, 1997b; Bennett & Dunne, 1991; Hennessy & Murphy, 1999; Rath & Brown, 1996; Roden, 1999; Roth, 1995, 1997; Shepardson, 1996).

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These studies provide preliminary evidence of the nature of children's talk during design technology activities. Researchers note that task-setting and purpose influence modes of talk, that a variety of modes of talk may be evident in any one particular activity, and that talk seems rarely to be devoted to the conceptual underpinnings of the lesson. During technology tasks, children can display flexibility in their thinking as they negotiate the task and work with others to achieve the objective. Although these findings provide useful groundwork, much has yet to be done as far as shaping these and other observations into a framework that lends itself to critical analysis that assists in identifying what children's technology talk could be.

A smaller number of studies have focused on how design professionals use talk to further the design process (Cross & Cross, 1998; Darke, 1979). Some researchers have speculated that professional discourse practices can provide some indication of the kinds of design talk that could be promoted during children's classroom design experiences (Gustafson & MacDonald, 2004; Hill & Anning, 2001a, b). Studies show that professionals' verbal decision-making includes using talk to frame the problem, gain an overview of the problem space, discuss constraints, make decisions, and discuss design trade-offs. Although researchers caution that professional discourse practices do not map directly onto the classroom, at the least these studies provide an overview of possibilities for children's design talk.

Other strategies that can be used to generate, explore, and modify design technology ideas include drawings, observing and recording, and building prototypes (Kimbell, Stables, & Green, 1996). Within this array, drawing is the visual tool that professional designers view as being the critical medium of design (Cross, 1989; Robbins, 1994). Designers view drawing not just as a way of recording images but as a concrete mode of thought, a mediating instrument between mind and hand, between abstract thought and reality. Drawings are used to both represent and to generate ideas. For the design of most complex products, this means that thousands of drawings may be necessary. Because it has been suggested that designers not only communicate visually but also think visually, we refer to the processes represented by the drawings as visual decision-making.

Recent research on classroom drawing in design technology has focused on four main questions: How is drawing used as a means of creating and developing ideas? What is the link between drawing and making? What are the respective roles of 2-dimensional and 3-dimensional modeling? And what are the effects of the explicit teaching of drawing? Researchers report that classroom design technology drawing overemphasizes the role of drawing in representing and communicating ideas and under-emphasizes its role in generating ideas (Anning, 1997a; Garner, 1992, 1994; Hope, 2000; MacDonald & Gustafson, 2004; MacDonald, Gustafson, & Gentilini, 2007; Smith, 2001). Disparate findings have been reported on whether or not children use their drawings to assist with building (Fleer, 2000; Rogers, 1998). Children have been found to prefer 3-dimensional modeling to 2-dimensional drawing and appear reluctant to use sketch drawings (Smith, 2001; Welch, 1998). Researchers have recommended that a potential strategy to enhance children's use of design drawing is to teach children drawing skills in an effort to make them more aware of the ways drawing can contribute to their designs (Fleer, 2000; Smith, 2001; Smith, Brochocka, & Baynes, 2001). These studies provide insight into the challenges of children's design technology drawing and show some promising direction for what children's design technology drawing could be.

In the study reported on in this paper, we propose that ideas about talking and drawing derived from interactions between children and university industrial design students can be useful for discerning possibilities for children's classroom talking and drawing. Studying professional practice is a longstanding tradition in education that in science education has led to the development of lists of science processes (AAAS, 1967), and in language arts education has led to the generation of the writing process (Walshe, 1981). In design technology, Davies (1996) argues that professional designers and children have much in common (e.g., thought processes and approaches to their work) that justifies using professional practice as a way to inform work with children. Medway (1994), however, warns that technological education is not technological practice as each works within a distinctively different matrix. In this study, we concur with Medway (1994) who concludes that studies of professional practice can provide indicators of curricular possibilities and add that studies of interactions between children and novice practitioners hold the possibility of assisting teachers to understand how to enrich children's design technology talking and drawing.

Basing the study on potential insights that can be observed through having children collaborate with a more knowledgeable person also draws upon ideas about scaffolding found in the social constructivist model of learning (Vygotsky, 1968). Scaffolding is the support provided to children by the knowledgeable other and can include recruiting the child's interest, highlighting critical aspects of the task, limiting task frustration, and demonstrating solution paths (Wood, Bruner, & Ross. 1976). A critical aspect of scaffolding is what Vygotsky terms the zone of proximal development (ZPD). The ZPD is described as the distance between the child's actual development and the higher level of potential development that could be achieved through the guidance of a more knowledgeable other (Wertsch, 1985). In design technology, some studies have focused on what might be involved in scaffolding children's design learning (Kolodner, et al., 2003; Puntambekar & Kolodner, 2005). Studies have helped to identify tools and agents of support and emphasize the importance of creating contexts in which learning conversations can occur.

Question: How can studying children as they work with university industrial designers provide direction for children's classroom talking and drawing?

Methodology

One elementary school located in an upper class, urban neighborhood was selected for the study. Researchers visited one Grade 3 (16 boys, 10 girls) Academic Challenge (e.g., gifted and talented) classroom during an 8-week unit on *Testing Materials and Designs* and *Building with a Variety of Materials*. Within the 8-week unit, the children studied drawing (2-dimensional and 3-dimensional), the design process, the importance of planning, furniture and structural design, and how to build with various materials.

This paper focuses on five weeks of the unit during which the children worked to design a piece of furniture that had more than one function (e.g., a lamp that illuminated a room and also contained an alarm that would warn of an intruder). The children's work began in their school classroom where they were introduced to the concept of design, taught drawing skills relevant to design, and taught the meanings of the terms furniture, need, and function. Each child then made three initial design drawings of their piece of furniture.

During the next few weeks, the children participated in three visits to a local university to work with industrial design students, collaborate on their furniture designs, and produce posters of their final design ideas. During the first visit, each child was paired with a university industrial design student who was referred to as a "Big Buddy." The children's initial design drawings were scanned into their Big Buddy's computers and the university industrial design students then provided the children with short explanations of the Rhino(ceros) graphics program being used. Over the next two visits, children worked with their Big Buddies to refine, improve, and complete the design. During the final visit, children shared their final designs with the class and the Big Buddies printed the design ideas onto posters. These posters were later exhibited at a venue during a local annual art show.

During the study, audiotapes were made of whole-class discussions that occurred prior to and after the university visits. Anecdotal records were kept of informal conversations with the teacher that occurred prior to and after each lesson. Lesson transcripts were provided to the teacher, and she was invited to amend or clarify the meaning of any verbal comments. Field notes and photographic evidence were compiled to gain insight into the children's interactions with each other in the classroom and with their assigned Big Buddies. Children's drawings and writings were photocopied and used to help interpret verbal comments. The children also completed a written pre- and post-study survey about their perceptions of design.

During the three university visits, audiotapes were made of four dyads, each consisting of a child (2 girls, 2 boys) working with an industrial design student. Transcripts were prepared from these audio-taped sessions. After each of the visits, the university industrial design students completed a post-visit questionnaire. Questions included asking about the children's tasks, decision-making, and design challenges and the nature of the university students' assistance and guidance.

Data Analysis

Audiotape transcript analysis of the four dyads (Ch1/USt1; Ch2/USt2; Ch3/USt3; Ch4/USt4) began with categorizing how the four children and their Big Buddies used talking and drawing to negotiate the nature and context of the task. Through multiple readings of the data, profiles were developed of the ways in which talking and drawing were used to achieve design solutions (Huberman & Miles, 1994). Industrial design student questionnaires derived from the entire class were used to expand the description of interactions between children (coded as Ch #) and university industrial designers (coded as USt #), and records of drawings and poster presentations were used to help clarify ongoing and final thoughts. Audiotape transcripts of whole class discussions that occurred prior to and after the three university visits (coded as Vis 1, Vis 2, and Vis 3) helped to show how the children's ideas were evolving and provided evidence to support interpretations made about the children's talking and drawing.

Findings and Discussion

During data analysis, it became apparent that the university industrial design students used a combination of talking and drawing to help the children achieve design solutions. Talking and drawing was characterized by a university student and a child working together to sift through ideas, refine their ideas, negotiate constraints, and arrive at plausible design solutions.

Design Talk

During the first visit to the university, talk was used to:

- Discuss the overall design (e.g., What need is being met? What is the function of various components? How can we understand the initial drawings?).
- Simplify the design (e.g., What can be removed? What is really important?).
- Add to the design (e.g., What should be added to address the original need?).
- Decide on specifications (e.g., Where should parts be placed? What materials could be used? What are favorite colors? What are the dimensions?).
- Explore the child's life (e.g., What are the child's likes and dislikes?).
- Explore the plausibility of the design (e.g., What is technologically possible? What cannot be built?).

After this first visit, university students generated new renderings of the children's original designs and these renderings became the focus of the second visit.

During the second visit, talk was again used to add to the design, simplify the design, and decide on specifications. New to the second visit was talk about:

- Whether the design met with overall approval (e.g., Are we satisfied with our decisions? Is this reasonable?).
- The name of the design (e.g., What will we name it?).

After the second visit, the university students revised the designs to share with the children during the third visit.

During the third visit, children with completed renderings were asked to present their ideas to the audience. In preparation for this presentation, talk centered on:

- How to describe the device (e.g., What are the important features?).
- How to use the device (e.g., How will we use this? What is the function of each component?), and if not already named,
- What to name the device (e.g., What will we name it?).

The children had great imaginations but these ideas had to be tempered by the university students' ideas about what was workable (e.g., "It is hard to tell them something is not possible." – USt 6, Vis 3; "It was difficult for the child to narrow down her ideas to something that was somewhat realistic." - USt 1, Vis 3; "The child ignored physical realities and expected things that were not very likely." – USt 6, Vis 1). Some children had to be guided to acknowledge that some design elements were not plausible (e.g., "Would it be reasonable to believe that the couch would be able to hover into space? We decided no." – USt 24, Vis 2; "She set out to think up something kind of crazy and fantastical. She was very willing to discuss those aspects of the design that were too far away from today's technology. She was agreeable to making compromises as the design progressed." – USt 24, Vis 3).

Some children added detail just for the sake of adding detail (e.g., "He had to remove some of the functions of his design to simplify it." – USt 26, Vis 1; "He sometimes wanted to add superfluous ideas." – USt 10, Vis 3), and a small minority of children had difficulty expressing ideas verbally (e.g., She was quiet and shy. She found it hard to express her ideas and she wasn't really sure what she wanted to design." – USt 18, Vis 1).

Many university students were seen to engage in a verbal iteration between the children's needs and wishes and their own adult designer knowledge (e.g., "The child decided just about everything from style, color, most functions and placement of components. I came in to give a general sense of some limitations and other needed adjustments." – USt 7, Vis 1; "All of the ideas came out of dialogue with her and I. She was very open to making suggestions and thinking up new ideas." – USt 8, Vis 2). To move forward, university students had to teach the children the language of design (e.g., perspective view). In turn, children had to teach the designers their language for describing the design and the manipulation of that design (e.g., 'diagonal' view).

Overall, talk was characterized as a social process and was used to frame the problem (What is possible? How does this connect to the child's life?), identify the needs being met by the device (What need is being met?), gain an overview of the problem space (What are we trying to solve?), help identify a variety of constraints (What cannot be built?), consider a wide range of design alternatives (What are important features?), negotiate trade-offs (What should be added or removed?), name the design, and assess the plausibility of the designs (Is this reasonable? What is technologically plausible?). Clearly, talk acted as a verbal tool that children and university students used to take design ideas forward. As one university student wrote:

> We went through different aspects of design, such as legs, doors, arms, hands, shelves, etc. This sparked new ideas. For example, we talked about a base for the shelf, then I suggested legs. This gave the child the idea of incorporating wheels on the bottom which led to the idea of having a cabinet sit on the table for you. Having him think about different aspects sparked more ideas. (USt 10, Vis 1)
>
> We talked about potential issues in problems with the design and we tried to solve them together. Discussing different options. Thinking about specific issues helped him think of solutions. (USt 10, Vis 2)

At times, the university student and the child encountered some impasse that could only be resolved through visualization on the computer or in sketches. In the next section, we discuss how drawing was also used to take ideas forward.

Design Drawing

Children made a series of initial sketches prior to their first visit to the university. These sketches showed the children's initial thoughts and were exploratory rather than representational. Although these initial sketches were ambiguous and incomplete, making them helped clarify initial ideas and gave rise to new ideas and alternatives. The time spent in the classroom on these initial sketches featured a constant interplay between "head and hands," thinking and acting.

During the work with the university students, drawing was used to transform ideas expressed in the initial sketches. The dyads spent time elaborating, refining, expanding, and developing initial ideas. Drawings showed increasing accuracy, detail, and dimensions. The final presentation drawings were recognizable representations of the finished idea and were presented in poster format (see Figure 1).

University students wrote on their questionnaires that drawing helped develop ideas in the following ways.

- Drawing helped the children to describe their own ideas (e.g., "The child also continued to draw a little bit to describe what he wanted." – USt 5, Vis 2; "We went through the child's initial drawings and I tried to understand all the little details. When I didn't understand, she would redraw them so that I would understand better." – USt 23, Vis 1).

- Drawing helped university students to describe their own ideas (e.g., "If I drew something and showed what I was thinking he would realize what I was doing and be able to add input." – USt 6, Vis 2).
- Drawing was used to provide a visual representation of the children's verbal ideas (e.g., "Having the child describe what she wanted in a piece of furniture but having me draw them out on paper." – USt 5, Vis 1; "Sometimes I found it difficult to fully understand what he was describing to me. It helped to sketch things out." – USt 2, Vis 2; "I would draw out what the child was describing to try and identify what he was trying to communicate." – USt 9, Vis 1).
- Drawing was used to continually represent ongoing design ideas and take those ideas further along the path to completion (e.g., "Seeing the final presentation made her realize what was missing."- USt 26, Vis 3; "The more we discussed what she had drawn, she was able to elaborate on her ideas and describe to me in greater detail exactly what her ideas were and together we came up with more details." – USt 24, Vis 1; "The sketches I had done allowed him to see what we had discussed and having a visual allowed him to make further decisions about details and function." – USt 10, Vis 3).

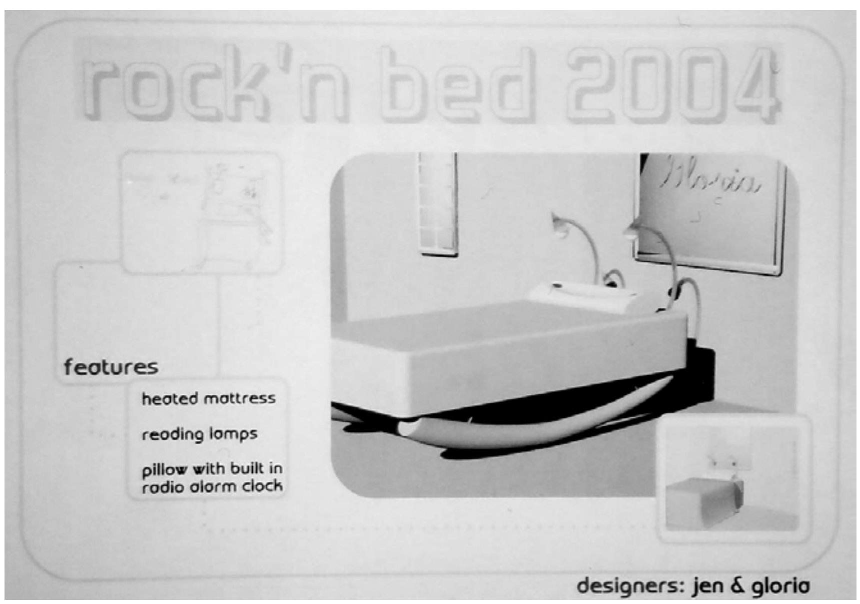

Figure 1. Example of a final poster.

Overall, drawing was characterized as a tool that could be used to generate and represent design ideas. All of the children and the university students held conversations about designing through the medium of drawing with pencils, felt markers, and computers (e.g., “Different colored pens helped better communicate different functions and materials.” – USt 13, Vis 1). The children drew their ideas, university students drew the children’s ideas, university students drew their own ideas, and the children drew the university students’ ideas. There was a continuous representation of ongoing ideas.

Of particular interest was the role of the computer in representing ongoing ideas. Prior to the university visits, the children had minimal exposure to using a computer to draw and all but one stated a preference for using pencil and paper. At the university, however, the children appeared intrigued with the Rhino(ceros) software and the design possibilities it represented. University students wrote on their questionnaires that the computer assisted the children in the following ways.

- Visualizing in three dimensions (e.g., “He had difficulty visualizing ideas in three dimensions and the computer aided him in this sense.” – USt 5, Vis 3; “Building the object in 3D space and applying color and texture allowed the child to relate better.” – USt 15, Vis 1; “By bringing the design into 3D space the child was able to better communicate his ideas and become more excited and interactive.” – USt 12, Vis 3).
- Showing all views (e.g., “To show them the final piece altogether and the ability to pan over the object 360 degrees in computer space.” – USt 4, Vis 3).
- Trying different features and enhancing quality (e.g., “The computer allowed her to choose curves, textures, colors, etc. with ease instead of describing it to me.” – USt 26, Vis; “The computer helped me to show a better quality drawing to the children and to increase their attention on what we can all do for this project.” – USt 11, Vis 3).
- Giving immediate feedback (e.g., He got to see immediate shapes and let me know what he didn’t like.” – USt 2, Vis 3).
- Researching information (e.g., As a tool to find information and inspiration online.” – USt 20, Vis 3).
- Virtual making (e.g., “It allowed us to have a final result without actually building the prototype.” – USt 20, Vis 3).
- Introducing play (e.g., It aided visualization and offered an element of play.” – USt 17, Vis 3; “It made the exercise more exciting, it helped to keep him interested in the task.” – USt 5, Vis 3; “It made the project more fun.” – USt 10, Vis 3).

In summary, the computer helped to visualize possibilities, enhanced design communication, and made it easier to move forward with an appropriate design. The computer was used together with sketches to clarify ideas and visualize the product. As one university student wrote:

> The computer helped a lot in precise, very realistic ideas and products. However, sketching helped at the initial stages to get the idea clear. The computer also enabled us to try different colors, features, materials, to see which one she liked the most. (USt 18, Vis 3).

Along with talking, drawing acted as a vehicle for design decision-making – much as both do for professional designers. Frequently, talking and drawing were interconnected. At times, when children struggled to find the words to represent their thoughts, drawing substituted for the verbal expression of ideas. At other times, drawing worked in concert with talking to clarify children's ideas, expand the range of design possibilities, and arrive at plausible solutions. As one university student wrote, "I learned how difficult it is to verbally describe ideas without visual backup. Also, how to plan and create the right questions to get a full sense of what the client wants" (USt 22, Vis 3).

Design Teaching and Learning

During the project we had to keep in mind that the children were not just engaged in a design project but in a pedagogical project. In other words, the goal was not just to design something and produce a poster but also to teach the children about design and technology. Thus, the project had both a product purpose and various teaching and learning purposes. Kimbell, Stables, and Green (1996) provide a useful way of categorizing teaching and learning purposes for design projects based loosely on the commonly used educational framework of learning goals as encompassing knowledge, skills, and attitudes.

Kimbell, Stables, and Green (1996) suggest six main teaching and learning purposes:

- Enriching content knowledge.
- Extending knowledge of the nature of technology.
- Enhancing knowledge of the nature of technology.
- Developing skills.
- Developing individual attitudes.
- Promoting group working styles.

The following examples show how each of these teaching and learning purposes was met within the context of this research project.

- Enriching content knowledge: During their talking and drawing, the university students taught the children about the key elements of design - line, shape, mass, texture, color (e.g., "We talked about viewpoints and 3D drawings. I explained what perspective view was which he called diagonal view. I also told him that if you draw something straight on from the front and sides, it can be more descriptive than a confusing perspective drawing of all the sides. I also showed him a little bit about Rhino." – USt 6, Vis 1).
- Extending knowledge of the nature of technology (design processes): The teacher and the university students helped the children learn about the importance of planning, designing, and drawing (e.g., Planning - "When

you want to create something you always need a plan. Whether it's writing or sketching, it's useful." – Ch 24; Designing - "Design means plan, create, and build. To me it seems like a process of building." – Ch 11; "Design to me means a 1D or 2D drawing that comes to life most of the time in a 3D object." – Ch 18; Drawing – "They make a rough copy and then they look back on it and see what they can improve on. Then they improve it and then they create it." – Ch 18).

- Enhancing knowledge of the nature of technology: University students taught the children that design operates within certain constraints and safety considerations (e.g., "And then if you press the button the shower will come down. Okay. Do you want to have it over here or do you want it away from … because it probably couldn't be that good to have it by the electricity." – Ch 1/USt 1, Vis 1).
- Developing skills: University students taught the children how computer graphics can help them to visually represent their design (e.g., "We just move it down a bit here. You see? So now you have a three-dimensional box on the computer [screen]. That's usually how it works." – Ch 2/USt 2, Vis 2).
- Developing individual attitudes: The children learned that much time and work is required to complete a design project (e.g., "I learned that it takes a lot of patience to make a full design." – Ch 8).
- Promoting group working styles: The children learned the benefits of collaboration (e.g., "Working with someone from the University made me proud. I really enjoyed using my Big Buddy's markers with the skinny and fat ends." – Ch 24).

In summary, the project provided children with a context in which they could learn about the complexity of design and expand their conceptual and procedural understanding of the design process – especially with respect to the role of talking and drawing in developing a plan. The richness of their interactions with the university students helped the children to contemplate their ideas and consider alternatives. In the end, the children were challenged to re-examine their ideas and assumptions and provide support for their decisions resulting in designs that told a story of the iterative and recursive nature of their work.

Implications for Classroom Practice

The original question was whether or not this study could provide some direction for design technology classes conducted in elementary classrooms. Previous discussion based primarily on the university students' questionnaire responses suggests that implications can be drawn for the kinds of talking and drawing that could be encouraged in elementary classrooms. In addition, these ideas suggest revisions to current models of classroom design.

In elementary classrooms, children's design drawing could be developed in the following ways:

- Teach children about the different kinds of design drawings and their role in generating and representing design ideas. Types of design drawings include initial sketches, ongoing drawings, and final design representations (e.g., "When I asked him to try drawing different shapes his product could be, he stayed with very simple geometric forms like triangles and circles and had difficulty imaging a similar object in 3D." – USt 5, Vis 1; "Today I showed her a whole bunch of sketches that I created over our discussion from last time. I also had some main design sketches for her to choose from. We created a new sketch together that incorporated some more of her ideas." – USt 18, Vis 2).
- Teach children how to draw using a variety of perspectives. Perspectives could include top, side, and magnified views of the design ideas (e.g., ; "She knew that for communication of her design to be easy, she had to draw her design in several different views." – USt 26, Vis 3; "He liked to see the project on the computer and would have liked to manipulate it in the perspective views." – USt 17, Vis 2). Also, if classroom projects involve the opportunity to build designs, the accuracy and completeness of the drawings can be tested by having children build each other's designs.
- Introduce design alternatives during drawing to help children understand the importance of planning, incompleteness of plans, and the complexity of design decision-making (e.g., "The computer allowed her to see in a 3D way, the ideas that she brought to me originally. In this case, it was easier to move forward with appropriate design changes. Also, it was very simple to change color and material choices to view a number of different looks." – USt 24, Vis 3; "I learned not always to go with your first design idea, but to think of as many ideas as possible without worrying too much about what the end result will be." – USt 8, Vis 3).
- Direct children to draw several potential design solutions then provide a rationale for choosing one to pursue in more detail (e.g., "I would have the child come up with more than just one idea and get him to push his ideas further." – USt 5, Vis 3; "I would push the initial concept further before we take it to completion. Give the child complete artistic control." – USt 31, Vis 3).

Opportunities for enriching the level and extent of talk in elementary classrooms could include:

- Providing time for whole class discussions about important concepts and anchoring terms related to the design project in order to develop a language of common practice (e.g., "Some concepts they had were difficult to follow and took quite a bit of explaining." – USt 22, Vis 1; "Questions. I can't emphasize the importance of asking questions. It makes the child make considerations he or she never thought about. Also, encouragement is helpful. Try not to criticize their ideas unless you are following it up with perhaps a more plausible solution." – USt 16, Vis 1; "I learned the importance of asking the client a lot of questions and not expecting him to give a lot of information unless asked. I also learned that being able to draw your ideas out quickly is an extremely important skill when collaborating with a non-designer." – USt 3, Vis 3; "I asked questions in order to narrow down the most important features and how they would specifically work." – USt 24, Vis 2).

- Teacher guided conversations that assist children to think critically about design constraints (user, physical, and material), how to balance illusion with reality (i.e., what can be dreamed up versus what can actually be done), how to sift through and refine ideas, and the nature of ongoing design ideas (e.g., "He wasn't as critical as I was hoping. I thought he would say, 'I like this part of this drawing and the light and armrests on this one. Instead, he just said 'Cool! I like this chair!' and I wasn't able to determine what he liked about it." – USt 22, Vis 2; "We also talked about how we could take her initial idea – which was very 'out there'- and transform it into something slightly more practical." – USt 8, Vis 2; "We discussed what his original ideas were and then proceeded to define what features specifically achieved. We went through several steps of analyzing possibilities and weeding out those that might not be possible or useful or 'cool'. We eventually settled on a specific product with a manageable set of features." – USt 3, Vis 1; "I would try to get the child to try and communicate their ideas to me a little bit better. I did like the fact that when we communicated, we put both of our ideas together and came up with something." – USt 18, Vis 3).

The study also showed the benefits of collaborating with an older, more knowledgeable adult to reach some higher level of understanding. This finding relates to Vygotsky's notions of social cognition and the zone of proximal development (Vygotsky, 1968). Collaboration afforded the children the opportunity to expand their workable ideas and design possibilities and modeled the team approach to design seen in the profession. Children were encouraged to think outside the box, for example, to understand that designs must meet the needs of multiple users. In classrooms, collaboration tends to be with the teacher who may or may not have sufficient time available to mentor each child. To expand collaborative possibilities, teachers can arrange for children to work with students in later grades who have some design experience. Guest designers can also be invited to classrooms to talk about their work experiences and provide feedback to the children on their work.

Conclusion

The purpose of this project was to see whether pairing children with adult, novice industrial designers would reveal some possibilities for how to enrich children's classroom design technology talking and drawing. Certainly the opportunity to work with more knowledgeable adults was key to the children's experiences, but through these experiences emerged messages for teachers working with young children in design technology classrooms.

Teachers can enrich children's design technology experiences by helping children to: expand their design horizons beyond satisfying their own personal needs and wants, realize that design operates within certain constraints, place realistic dimensions on their designs, visually generate and represent their ideas on paper and perhaps with the assistance of a computer graphics program, understand key elements of design (e.g., line, shape, mass, texture, color), understand the processes of design (e.g., considering alternatives, engaging in opportunistic design), and collaborate with others.

Design technology models featured in school programs present an oversimplified view of design. Even models that emphasize the iterative and recursive nature of the design process do not capture the time and guidance children need in order to achieve thoughtful design solutions. In order to bring children closer to a more authentic approach to design, greater emphasis should be placed on how to work together to use talking and drawing as tools for thinking about design.

References

AAAS (1967). *Science: A process approach*. Washington, DC: American Association for the Advancement of Science.

Anning, A. (1997a). Drawing out ideas: Graphicacy and young children. *International Journal of Technology and Design Education*, *7*, 219-239.

Anning, A. (1997b). Teaching and learning how to design in schools. *Journal of Design and Technology Education*, *2*(1), 50-52.

Bennett, N., & Dunne, E. (1991). The nature and quality of talk in cooperative classroom groups. *Learning and Instruction*, *1*, 103-118.

Cross, N. (1989). *Engineering design methods*. New York: Wiley and Sons.

Cross, N., & Cross, A.C. (1998). Expertise in engineering design. *Research in Engineering Design*, *10*, 141-149.

Darke, J. (1979). The primary generator and the design process. *Design Studies*, *1*(1), 36-44.

Davies, D. (1996). Professional design and primary children. *International Journal of Technology and Design Education, 6*(1), 45-59.

Fleer, M. (2000). Interactive technology: Can children construct their own technological design briefs? *Research in Science Education*, *30*(2), 241-253.

Garner, S. (1992). The undervalued role of drawing in design. In D. Thistlewood (Ed.), *Drawing Research and Development* (pp. 98-109). Burnt Mill, UK: Longman.

Garner, S. (1994). Drawing and design exploration and manipulation through two-dimensional modeling. In J. Smith (Ed.), *National Conference in Design Technology Research and Curriculum Development (DATER 89)* (pp. 43-50). Loughborough, UK: Loughborough University.

Gustafson, B.J., & MacDonald, D. (2004). Talk as a tool for thinking: Using professional discourse practices to frame children's design technology talk. *Canadian Journal of Science, Mathematics and Technology Education, 4*(3), 331-351.

Hennessy, S., & Murphy, P. (1999). The potential for collaborative problem solving in design and technology. *International Journal of Technology and Design Education*, *9*(1), 1-36.

Hill, A. M., & Anning, A. (2001a). Comparisons and contrasts between elementary/primary 'school situated design' and 'workplace design' in Canada and England. *International Journal of Technology and Design Education, 11*(2), 111-136.

Hill, A. M., & Anning, A. (2001b). Primary teachers' and students' understanding of school situated design in Canada and England. *Research in Science Education, 31*, 117-135.

Hodson, D. (1998). *Teaching and learning science: Towards a personalized approach*. Buckingham: Open University.

Hope, G. (2000). Beyond their capability? Drawing, designing and the young child. *Journal of Design and Technology Education*, *5*(2), 105-114.

Huberman, A. M., & Miles, M. B. (1994). Data management and analysis methods. In N.K. Denzin & Y.S. Lincoln (Eds.), *Handbook of Qualitative Research* (pp. 428-444). Thousand Oaks, CA: Sage.

Kimbell, R., Stables, K., & Green, R. (1996). *Understanding practice in design and technology*. Buckingham, UK: Open University Press.

Kolodner, J.L., Crismond, D., Fasse, B., Gray, J., Holbrook, J., & Puntambekar, S. (2003). Putting a student-centered Learning by Design curriculum into practice: Lessons learned. *Journal of the Learning Sciences, 12*, 485-547.

MacDonald, D., & Gustafson, B. J. (2004). The role of design drawing among children engaged in a parachute building activity. *Journal of Technology Education, 16*(1), 53-69.

MacDonald, D., Gustafson, B. J., & Gentilini, S. (2007). Enhancing children's drawing in design technology planning and making. *Research in Science and Technological Education, 25*(1), 59-75.

Medway, P. (1994). The language component of technological capability: Lessons from architecture. *International Journal of Technology and Design Education*, *4*(10), 85-107.

Orsolini, M., & Pontecorvo, C. (1992). Children's talk in classroom discussions. *Cognition and Instruction, 9*(2), 113-136.

Parker, L. (1992). Language in science education: implications for teachers. *Australian Science Teachers Journal, 38*(2), 26-32.

Puntambekar, S., & Kolodner, J. L. (2005). Toward implementing distributed scaffolding: Helping students learn science from design. *Research in Science Teaching, 42*(2), 185-217.

Rath, A., & Brown, D. E. (1996). Modes of engagement in science inquiry: A microanalysis of elementary students' orientations toward phenomena at a summer science camp. *Journal of Research in Science Teaching*, *33*(10), 1083-1097.

Robbins, E. (1994). *Why architects draw*. Cambridge, MA: MIT Press.

Roden, C. (1999). How children's problem solving strategies develop at Key Stage 1. *Journal of Design and Technology Education*, *4*(1), 21-27.

Rogers, G. (1998). *The designing stage of design, make, and appraise: A case study involving young children designing*. Paper presented at the Australasian Science Education Research Association, Darwin, Australia, July 9-12.

Roth, W. -M. (1995). Inventors, copycats, and everyone else: The emergence of shared resources and practices as defining aspects of classroom communities. *Science Education, 79*(5), 475-502.

Roth, W. -M. (1997). Interactional structures during a Grade 4-5 open-design engineering unit. *Journal of Research in Science Teaching, 43*(3), 273-302.

Shepardson, D. P. (1996). Social interactions and the mediation of science learning in two small groups of first-graders. *Journal of Research in Science Teaching*, *33*(2), 159-178.

Smith, J. (2001). The current and future role of modeling in design and technology. *Journal of Design and Technology Education*, *6*(1), 5-15.

Smith, J., Brochocka, K., & Baynes, K. (2001). A pilot study into the value of 3D sketch modeling at Key Stage 3. *Journal of Design and Technology Education*, *6*(2), 125-138.

Vygotsky, L. (1968). *Mind in society*. Cambridge, MA: Harvard University Press.

Walshe, R. (Ed.) (1981). *Donald Graves in Australia – "Children want to write…".* Rozelle, NSW: Primary English Teaching Association.

Welch, M. (1998). Students' use of three-dimensional modeling while designing and making a solution to a technological problem. *International Journal of Technology and Design Education*, *8*, 241-260.

Wells, G. (1995). Language and the inquiry-oriented curriculum. *Curriculum Inquiry, 25*(3), 233-269.

Wertsch, J. V. (1985). *Vygotsky and the social formation of the mind*. Cambridge, MA: Harvard University Press.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 17*, 89-100.