Design Technology in the Elementary School—A Study of Teacher Action Research

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This article addresses the effects of requiring action research projects in the education of classroom teachers as mandated by a graduate program in elementary education. The Master of Arts Program in Elementary Education with a specialization in Mathematics, Science and Technology (MST), is designed for experienced elementary school teachers who seek the skills and knowledge, and attitudes and dispositions, to integrate the teaching of these areas. Technology is defined as *design technology* (DT), which encompasses the study of the technological world that inventors, engineers, and other innovators have created. It includes within it *information technology*, the integration of skills that require the use of computer applications to enhance student learning of mathematics and science.

Design technology is applied to the study of elementary science and mathematics to enhance and deepen elementary school students' conceptual understandings in these areas. Elementary school teachers are required to create and implement a unit centered on design technology that demonstrates connections among mathematics, science, and technology in their classrooms. They are then required to conduct research in their classrooms to examine the effects of implementing this unit on student learning, attitudes, and dispositions, as well as on their personal professional development.

This graduate program requires that the action research initiative be documented as a culminating experience through the writing of the Masters Thesis. This interdisciplinary Masters Program challenges elementary school teachers to integrate mathematical analysis, scientific inquiry, and technological design (DT) in multiple curriculum areas. Elementary school students who are engaged in units centered on design are involved in project based learning where they are using science and or mathematics concepts to design and construct a solution to a problem. DT integration is a vehicle for engaging students in their own thinking and problem solving by giving them the opportunity to direct their own learning. This paper addresses the effects of requiring teachers to use

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Design Technology with their own students and the effects of engaging teachers in research in their own classrooms.

Design Technology Connecting Mathematics and Science

While many teacher education programs integrate science and mathematics, few have added the component of design technology to the preparation of elementary school teachers; in New York State only two programs do so (NYSED, 2000). We address how the use of design challenges in their classes helped teachers give students more control of their own learning, hence, shifting their thinking about the role of the classroom teacher. Many educators talk about integration across the disciplines but at times the standards-based movement forces them to be more discipline based. "No matter what the content, we can design active linkages between fields of knowledge. An interdisciplinary approach to learning may be seen as a curriculum approach that *consciously* (italics added) applies methodology and language for more than one discipline to examine a central theme, problem or experience" (Jacobs, 1989). This is an appropriate description of an elementary grades DT unit that sets out to explore a mathematics or science topic and then to intentionally connect concepts from these disciplines to a design problem.

As the *Standards for Technology Literacy* (ITEA, 2000) note, becoming literate in the design process by acquiring the cognitive and procedural knowledge to create a design also has the potential for enhancing the students' understandings of the science and or mathematics concepts. One such example would be the design and construction of a model house for researchers in the heart of the rainforest. This house would need to occupy the least amount of surface area to make the smallest impact on the forest floor. In the actual rainforest, land is conserved when the houses are built on stilts and the house itself occupies the space between the floor and the canopy. By engaging students in designing an appropriate model for the rainforest, they apply their understanding of the constraints of the rainforest environment. In another DT unit on the human body, second graders designed and built a model skeleton with moveable joints. They needed an understanding of the ways in which joints operate to make a credible model. A deep understanding of the mathematics or science concepts is required for the students to engage in design and construction (ITEA, 2000, p.46).

Research addresses the importance of hands-on activities which, supported by meaningful discussion and theory building (Brooks and Brooks, 1993), help students construct meaning. Further, when students are encouraged to create artifacts (Appleton, 2000), they both reflect and enhance student understanding.

A constraint of the classroom research program described here is the required time frame. The students implement the integrated unit and do the research in the span of one semester. They are guided by two professors who visit with them in their classrooms as co-teachers and consultants. The students/classroom teachers are limited by needing to select a unit that is

congruent with the elementary school curriculum dictated by their school, grade level, and district.

What we have learned is that the very process of implementing a project-based DT unit, gathering data about it, and reporting their findings has had a profound impact on the teachers. This is consistent with the research on teacher inquiry or "action research" (Cochran-Smith and Lytle, 1999) which reveals that the teacher-researcher transforms herself as she knows and better understands her classroom and the process of teaching by inquiring into them. *In the On-Line Journal for Teacher Research* (2000), teachers reflect on the ways in which the process of inquiry has been professionally and personally transformative. "Teacher-research as an intentional and systematic study of our own classrooms and schools, is an emergent approach to study – *in situ* - and by the insiders – the educational phenomena taking place in the schools and classrooms. This approach is an *inside out* way of producing educational knowledge; that is from inside the schools and classroom"(Fischer, et al, 2000).

What distinguishes this teacher-research initiative is that it is mandated by academia, but implemented by the classroom teacher. The support of and guidance for teacher research yields valuable data for the field. This paper explores the following aspects of this DT-based teacher research initiative:

- The impact of classroom research to support the development of reflective practitioners;
- What teacher-research in DT reveals about student' abilities to direct their own learning;
- How interdisciplinary design-based projects engages students with special needs in a heterogeneous classroom.

Hence, this paper explores both the effects of a graduate program mandating teacher research and the effects of doing teacher research in the context of integrating design technology.

Framing the Conditions for Teacher Research

"Mathematics, Science, and Technology Education in the Elementary School," the culminating course in the MA/MST degree program, requires teachers to conduct an action research investigation in their own classroom. They are mentored through this experience by the co-authors, meeting weekly as a cohort, as well as having one-on-one meetings. At the beginning of the course, with the guidance of the course professors, the teachers create a unit, centered on design technology, which addresses conceptual understandings in mathematics, science, language arts, or social studies. In developing the unit, the teachers reflect many facets of their graduate education – e.g., learning outcomes, assessment strategies, diversity issues, connections to standards – to create a coherent unit that fits with each school's curriculum. As they are teaching the unit, they are writing their master's thesis, documenting their classroom research through several types of data collection.

The expectation is that each graduate student/classroom teacher will implement an integrated unit that addresses an elementary curriculum topic by

requiring their students to be engaged in design technology and related mathematics and/or science concepts. This integrated unit needs to be linked to local frameworks and reflects the culture of the geographic community in which the school is situated. After developing this unit, and before implementing it, teachers are asked to assess students' prior knowledge as well as their attitudes toward math and science. These baseline data provide meaningful information for the teachers and help them to assess student change by the completion of the unit.

For the research report, each teacher/graduate student is required to complete a six-part Masters Thesis that includes:

- A description of their setting and students;
- A review of the literature related to their topic;
- A plan for analyzing their students' attitudes and content knowledge, before and after implementing the unit;
- A description of the experience of implementing the unit for themselves and their students;
- An analysis of their data;
- Conclusions and Implications.

The teachers maintain a daily teaching journal, which serves as an important source of data as they describe the experience of teaching the unit. The professors maintain their journals about each teacher's research and use their final thesis publication as a source of data.

The professors provide support through weekly meetings, daily email communication, special conferencing, and visits to the classrooms. The following quote comes from a new first grade teacher implementing a DT unit about the seashore:

> I am less nervous with the daily lessons because my students have taken ownership and are quite interested. I am just nervous that we are not going to be able to study all the areas planned. Is that ok? Measurement has popped up as students attempted to describe a horseshoe crab. Living and non-living came up again. Students mostly associate living with humans. I am looking for suggestions on how to open this up a bit. I ask myself what should I expect from first graders? Should I be surprised like everything else?

Teacher research, also called action research or classroom research, is fraught with misinterpretations (Feldman & Minstrell, 2000). This project proceeds under the assumption that teachers who study the implementation as a long term unit with their students by collecting data, keeping a daily journal, describing the experience, and analyzing their data, and finally writing about it, are engaged in research. The program described in this paper mandates this form of classroom research.

The Design Challenge

"Technology Education in Elementary School," is one of the key courses in the MA/MST program. It introduces teachers to the field of technology education. A goal of the course is for teachers to become knowledgeable about and to use the design process. In the context of learning about design through activities and projects, other goals are achieved as well. Teachers become familiar with tools, resources, and materials that are available and can be used in an elementary school classroom. They use a design portfolio that guides and documents student work and thought, and they learn how to adapt it for a particular unit. Importantly, the teachers develop strategies to authentically assess student work based on the design process and the portfolio by using critiques of their own design projects and portfolios. Finally, they create activities with design at the heart that reflect an understanding of concepts in mathematics, science, and social studies.

Integrating design technology in elementary school and linking it to math and science is a vehicle for enhancing student learning in mathematics and science. Inherent in the design process is the problem to be solved that must perform certain tasks or meet certain specifications. The design challenge is limited by constraints such as materials available, time, and resources. When elementary students are required to meet design challenges, it encourages their individuality and critical thinking, and honors their own ideas. The presentation of the final product requires that students defend their ideas and therefore integrate their conceptual understanding of mathematics, science, and technology. For example, students are asked to report why they chose their specific design solutions and how they went about creating them.

As the teachers develop appropriate design challenges for their students, they are guided by the following question, "How does the design project enhance the students' understanding of mathematics and or science?" They are also guided by the ways in which they will assess what the students know and are able to do as a result of engaging in the design project. For example, one teacher implemented a unit on human body systems in the second grade. At various points in this unit, the children were asked to design and construct models of body systems using available materials. The chest vest consisted of a large paper bag with a hole on top for the children's head to peek through and armholes for each arm. Attached to the bag were three-dimensional models of the organs found inside the chest cavity. When the children wore their "vest" they were asked to describe each organ and its function. The students talked about why the organs were situated where they were. This design project presentation was assessed with the use of a rubric that guided both the evaluation and the student performance. This type of embedded assessment is typical for design projects.

Analyzing Teacher Projects

The source of data for this study was forty completed masters theses that documented the experience of using design technology with elementary school

students. The following research questions were addressed. As result of implementing this unit:

1. What changes, if any, did classroom teachers find in their students' attitudes towards mathematics, science, and technology?
2. What changes were noticeable in their own practice?
3. What emerged from the teachers' analysis that could be useful for informing future practice?

The analysis of these theses conformed to standard practice for data analysis, involving systematically searching through the sections of the text, organizing ideas, breaking them down into manageable units, and searching for patterns (Bogdan & Biklen, 1992). Interpreting and making sense of these teacher-authored documents involved giving special attention to parts four, five, and six of the Masters Theses where teachers documented the experience, the results of their assessments, and the implications for future work using design technology. Searching through these sections of the forty Masters Theses revealed three significant coding categories. These are a means of sorting the descriptive data that led to the emergence of three important themes that were revealed consistently throughout the teachers' theses.

These themes included (1) changes in teachers' own perceptions of their abilities to create student centered classrooms where each student group has control of the direction of their learning; (2) changes in students' attitudes towards mathematics, science and/or technology and in their understanding of the materials relating to the design process; (3) changes in the ways in which children with special needs engaged in group work and contributed to the final design project.

Working with a research assistant, we checked our data against an outside reader's and asked her to quantify the number of times each theme was mentioned in the forty theses. Out of the forty analyzed theses, thirty-eight teachers reported experiencing a shift in their teaching practice resulting in their changing perceptions of their role as teachers. Forty reported significant changes in student attitudes and comprehension as evidenced by pre- and post analyses of attitudes and understanding. What emerged in eighteen of the forty theses examined was the mention of the experiences of special needs students within the classroom setting. All eighteen studies noted the positive impact of design technology experiences for engaging students with special needs and encouraging them to be more active participants in the classroom.

Teacher Change

Becoming a teacher-researcher has been a transforming experience for the MA/MST teachers. Their view of themselves has changed from being someone who delivers instruction to someone who acts as a facilitator of students' developing knowledge. The districts where the teachers are employed vary tremendously in socio-economic terms. There are urban districts with overcrowded classrooms with children from single parent families and little home support, as well as affluent suburban districts with predominantly intact

families, and working class suburban districts that share many problems similar to those that the urban districts face. However, DT has transformed teachers in all settings. For instance, Michele reported:

> The results of this study and the children's enthusiasm are motivating me to apply this approach to all of my units of study. The children have learned such a great deal through the integration of mathematics, science, and technology into this unit on sound. I personally enjoyed the authentic assessment I was able to use with the children as a result of the activities in this unit. The process of observing them performing tasks gave me a better understanding of how to structure my classroom with more of a constructivist approach where the children are doing the inquiry.

Helping teachers to create "space" for students to actively seek solutions is a goal of the MST Masters Program. It is easier for some teachers and differs according to their current setting, background experience, and basic assumptions about teaching and learning. Challenging their assumptions and inviting them to critically analyze their philosophies is part of the program's pedagogical approach. Lisa G. noted:

> Taking into account the analysis of this total unit, the results have renewed my belief in and commitment to integrated MST teaching. Hands-on problem solving and decision making through design and construction have enabled my students to make many real life connections and become part of the world of math, science and technology that exists in the world outside of our classroom.

The awareness that children are able to have deeper understanding of material and make interconnections with the world around as well as other subject areas is demonstrated by Donna's observation:

> I have a new respect for my students after interacting with them as we implemented this unit…Prior to this unit I held a belief in the integration of curriculum, but now I have valid evidence that integrated curriculum is meaningful and promotes higher level thinking, conversation, and problem solving. Integrating all the subject areas is a worthwhile approach for all.

One teacher/graduate student implemented DT in the social studies curriculum in her district. In her fourth grade curriculum unit on Native Americans, she challenged the students to work in groups to design and construct models of Native American homes. The students had to connect the types of homes with the geographic regions where the tribes could be found and the ways in which the homes adapted to climates associated with these regions. This teacher (Cathy) remarked:

> Integrating the disciplines showed the class how pieces connect and fit together in real life. It shows how no one subject is isolated. Mathematics and

> science work together. Integrating the unit also allowed the theme to develop over time, and the students' interests were allowed to grow and expand. Isolating this unit into only social studies would not have given the students all the knowledge they have acquired. I feel turning a topic into a MST unit allows for ideas to flow and overlap which will provide the child with a deeper and more enduring understanding.

In addition to the insights the teacher-researchers were able to develop about how children learn, and how to authentically assess their levels of understanding, their input is sought in designing curriculum for the school districts. Lisa S. pointed out: "As a member of my district's science committee, it is my hope
that I will be able to encourage and assist my district in their desire to find the MST connections in our science curriculum. It is my hope that we will be able to eliminate some of the overlap that exists between grade levels and focus on 'quality rather than quantity.' By this I mean that I would like to see each grade focus on several integrated MST units per year rather than 12 segregated science topics."

Student Change

The graduate students/classroom teachers also reported how their students' learning was transformed. Students became active-learners, assuming responsibility for their own learning where the teacher was a guide, but no longer the sole resource. Michele observed that:

> From the integration of mathematics, science and technology into this unit on sound, I can conclude that every student became an active learner. The children demonstrated the ability to pose questions, seek answers, and test solutions. Each student turned into a 'problem-solving machine' as we underwent the challenge of constructing musical instruments. The scientific method of stating a problem, making a hypothesis, listing materials, planning a procedure for action, observing, recording observations and drawing conclusions was also exercised in this experience. The students were able to apply science ideas learned in this unit as well as previous units in order to build something.

The very goal of enhancing students' understanding of science concepts by asking them to design an artifact that applies those concepts is evidenced here. Further, Lisa S. reported that:

> It was evident that the children's perceptions of science had changed dramatically because of the enthusiastic way they approached doing the investigations, gathering data and the other aspects of the unit. As they took a more active role in decision-making and problem solving, they increased in confidence. Their discussion time really became a forum for the comparison of experiences and the sharing of new solutions and ideas. They no longer looked to me as the source of information or the solver of all of their problems.

> They now see themselves as 'knowers,' confident and capable of investigating possibilities and answers they needed to find.

The students' depth of understanding, making connections with the world around them is also enhanced by the DT unit. Danielle noted regarding a rainforest unit in which:

> Not only did the students gain knowledge about the importance of this sanctified habitat, but the students' confidence towards math increased, and their beliefs about science broadened. It is salient that the students have taken more responsibility for their learning as well. The students have become familiar with and have come to understand many concepts and ideas relating to the rain forest environment. They recognize how we are all part of an interconnected community where an individual's actions can have a direct or indirect impact on the environment.

In an integrated unit on the seashore, first graders were designing a three-dimensional model on a seashore mural. This involved measurement and early concepts relating to scale. Donna found that:

> By unleashing the students and giving them more control over what they were learning, more complex ideas were discussed. It was wonderful to see children integrating subject areas. Our science discussions led us to experiment, and to read literature and to do research. First graders were thinking about measurement, scale, and shape as they built their project. I saw students looking for rulers and cylinder-type materials to use for their projects. Students were making murals of the seashore at home before I even introduced the model seashore project. By the end of the unit students were attempting to write seashore poetry independently, which led to our lessons on poetry. In Writer's Workshop, students were writing books with a seashore theme before I even realized. They perpetuated the integration of subjects and benefited.

Critical thinking skills are so important to develop: the ability to analyze a situation, to apply the knowledge gained, and to gain new insights in the process of doing so. They pose questions and then seek solutions through their own investigations. Elizabeth noted:

> The students have improved in their research skills. This was evident by the contrast between their ability to look things up independently when I first arrived compared to this point in time. Many will now say they had a question, but found it in a book or on the Internet and discovered the answer for themselves. The students continued to research information on aviation after the "official" unit was over.

Jennifer corroborated this from observations of her class:

> Incorporating a design challenge is what made the unit come together. The students had all this information and nowhere to put it. It was during this

> part of the unit where everything clicked and the students began using the knowledge they acquired of the rain forest. The design brief and project, while relying on rubrics for assistance, then challenged the class. This was the first time students were given complete freedom to design a project with few constraints. The outcome is outstanding.

Special Needs Students

Many of the graduate students/teachers had classrooms where previously segregated students with special needs are mainstreamed into the life of the classroom. Another teacher joins the students, often contributing as a team teacher to the class instruction, while specifically supporting these students in learning activities. Consistently, teachers have reported that children with special needs, lower functioning students in the traditional academic setting, gain knowledge and self-worth while participating in DT units. They are able to equally participate in group design projects. Lisa G. noted that:

> The two students who were "lower functioning," who have experienced sporadic success by traditional methods, were able to participate fully and experience completion, sustained success, and share in the sense of accomplishment from a job well done

Lisa S. recorded a similar experience in her teaching journal.

> This unit also allowed lower-functioning students who had in the past experienced success rather sporadically, to now experience success on a daily basis. I feel that the reason for this is because the unit encompassed so many learning styles that each child was able to strive and succeed regularly. As a result, students felt better about themselves and were more willing to take risks not only during the work on this unit, but on work in other subject areas as well. Students who used to sit quietly and need to be called on were now active participants who shared willingly and weren't afraid to be wrong. They seemed to try harder and be more enthusiastic about what was happening in the classroom.

Ann Marie also noted that the unit on designing snail habitats could foster improved learning and understanding in her lower functioning students:

> The students' faces would light up when I mentioned the word "snail" because they realized that they were going to get to discuss how much they had learned followed by time to observe and explore the snails. . . . the low functioning students could share just as many snail facts as the others could. I was amazed that they could remember this information because if I asked them to spell their name they sometimes had trouble. These students can even give the definition of such words as hibernation and tentacles. They can not always pull the words out, but once the word is said they can define the term.

Tina found that integrating design minimizes the need for teacher intervention in DT unit on weather.

> I was happy and surprised to observe the significant amount of students who immediately wanted to participate when I asked for ideas to place on the first cloud. I noticed that one student's contribution would trigger a thought in another student's mind. Another thrilling experience for me was to witness my inclusion students participating in this activity, without teacher intervention. In the blended setting, the inclusion students tend to remain quiet because of the fear that the ideas they would like to share may be incorrect. The number of students in the class, along with their lack of skills, can cause extreme intimidation. As we completed this activity, however, they felt confident enough with the concepts they were familiar with, to offer many excellent ideas.

Conclusions

The graduates of the MA/MST program have improved their capacities for becoming reflective teacher/practitioners. The intensity of creating and implementing an elementary school unit centered on design technology in one semester is a challenge, one to which all have risen. Meeting with their peers who are experiencing the same process, conferencing with their mentors, and feeling the commonality of experience from frustration to jubilation, has furthered the realization of the transformations occurring in their classrooms. The transformation from teacher-centered to student-centered classrooms has caused them to reflect on how this has occurred. One point of consensus is the evidence that multi-disciplinary curriculum is meaningful and promotes higher-level thinking, conversation, and problem solving by children. Design is found to be inherently integrating; it is the keystone that brings the unit together. Teachers found that authentic assessment of student work caused them to further reflect on student learning and their role in that process. The process of observing students performing tasks provided an enhanced understanding of how to structure classrooms for a more constructivist approach to learning.

Equally important has been the willingness to shift to more student-centered learning and to monitor the students' enthusiasm towards learning. Their students became active learners and problem solvers. Indeed, their critical thinking skills, as evidenced by their ability to pose problems, seek answers, and test solutions, expanded and extended to other curriculum units. Their confidence increased, as they had to take responsibility for their own learning, becoming capable of researching, and finding answers to questions they posed for themselves. The questions became more complex and interrelated. No longer were curriculum areas isolated; mathematics, reading, writing and science are connected through design.

One of the most significant results from units centered on design is the benefit it has for inclusion students or students with special needs. All of the teachers who found that their inclusion students benefited from the experience, in ways they had not from traditional classroom learning activities, realized that the design process enfranchises a variety of learning styles, from the traditional academic instruction to the creative and eclectic.

In order to implement design technology, the teachers had to let go of their central roles in their classrooms and create a more student-centered environment. They were surprised at the way their students assumed responsibility for their own learning. Children, when empowered, more actively participate in class discussions and perform better in cooperative groups. This is accomplished as a result of their enthusiasm for the design process and the construction activity.

The process of writing about their experience, gathering the data, and analyzing the data deepens the teachers' capacities to think intellectually. By becoming thoughtful problem solvers, they enhance their own capacities for reflection. The professors continue to struggle with how to build upon the reported and observed strengths of integrating project based units into traditional elementary school curriculums. What continues to evolve is the powerful connection between graduate in-service teacher education and its potential for directly impacting daily classroom practice.

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