4. DEVELOPMENT OF TECHNOLOGICAL LITERACY IN GIFTED AND TALENTED ELEMENTARY SCHOOL STUDENTS

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Understanding how the universe works is fundamental to human nature, but needing to know has become essential for safely managing our future. It is our charge as educators to produce students with greater scientific and technological literacy, who can make informed decisions regarding technology in the 21st century. It is our charge to encourage highly competent, ethically responsible, young scientists and engineers, who will create future innovations and inventions that impact all global citizens. The International Technology Education Association (ITEA, 2000) urges the implementation of the Technology Content Standards in K-12, in all schools, to ensure technological literacy for all students.

Development of Technological Literacy in Elementary School Students

In order to forge ahead in developing a literate citizenry in science and technology, a clearer picture of the meaning of technology, must be presented that illuminates an understanding of its place in the elementary school curriculum. A useful synthesis of the most accepted definitions of technology, one that supports the current study, indicates that technology consists of

the knowledge, processes, and ingenuity that have enabled humans to conceive, design, and create tools and products as well as the systems that support them. Artifacts are made because people have needs or wants. They are made from a variety of materials, both natural and synthetic, dependent on their uses. They comprise the "built environment" in contrast to the "natural environment." (Wright, 1999, p. 2)

In today's technology-based society, it is imperative that students understand this built environment, including its social and environmental impacts, consequences, and by-products.

Technological Literacy

The main goal for the field of technology education (TE) is to promote technological literacy (ITEA, 1996). However, experts have had a difficult time coming to a consensus about what the concept of *technological literacy* entails. Dyrenfurth, Hatch, Jones, and Kozak (1991) explain technological literacy to be a multi-dimensional concept which includes the ability to use technology (the practical dimension), the ability to understand the complex issues raised by the use of technology (the civic dimension), and the appreciation for the role of technology in society (the cultural dimension). Similarly, ITEA (1996) defines technological literacy as "the ability to use, manage, and understand technology" (p. 6).

To achieve the broad and encompassing goal of technological literacy for all students, technology educators must provide and sustain a relevant education that will prepare students to understand, control, and use technology (Boser, Palmer, & Daugherty, 1998). All students, now living in a technological world, need to be able to adapt to the changes brought about by technology, identify and solve problems, and make appropriate decisions to deal with the various forces that have the potential to influence and control their lives and futures (Waetjen, 1985; Wright, 1999).

A vision for what students need to know and are expected to do in order to be technologically literate is being shaped by educators and professionals. Technology education (TE) researchers and educators (PATT 9 Conference) recommend recognizing TE as an essential core field of study in the school curriculum, and as the integrator of the knowledge and skills from the other content areas (de Vries, 1999). With technology now as the basis of our modern global economy, it is imperative to prepare all citizens to be technologically literate. Technology education would bring this essential literacy to all students. Like other literacy efforts, such as language literacy and numeracy, technological literacy will require knowledge and practice over time (Boser et al., 1998).

Elementary School Technology Education

Although the *Standards for Technological Literacy*: *Content for the Study of Technology* (ITEA, 2000) has been disseminated, research is needed to indicate the type of educational activities and experiences that will enable teachers in the elementary school classroom to meet the technology content standards. Teachers need to know how to connect the technology standards with what they currently teach, and how to create a technology-rich learning environment in the elementary school classroom. The intent of this type of environment is to engage children in authentic, real-world problem-solving; provide opportunities for students to access science and engineering experts in the field for the latest and most current information related to their questions; and to promote positive attitudes toward and greater understanding of technological literacy.

Elementary school technology education (ESTE) is not simply providing hands-on/minds-on activities for students; rather, it is an educational program that engages students in the development of their curriculum (Zuga, 1984, 1989). That is, it begins with where the student is in his/her understanding of a concept. It is a student-centered approach based on fostering a learning environment in which students can question, discover, explore materials, design, create, construct, solve problems and evaluate the impacts of technological designs (Wright, 1999). The curriculum becomes personally relevant for the student. Context gives meaning to school work and knowledge, and is an important factor for developing technological literacy.

Leaders in the field urge ESTE researchers to focus on (a) how teachers can best use their precious time to engage young people in journeys (engaging activities) that reach predetermined destinations (the attainment of standards), and (b) what students are learning from rich technological activities that use a problem solving approach to technology, and (c) how students learn the deep understandings and essential skills and processes for technological literacy, such as planning, designing, constructing, programming, testing, redesigning, and evaluating (Crismond, 2001; Lee, 1996; Welty; 1999).

Problem and Research Questions

There is scant amount of research conducted in the area of elementary school technology education (ESTE). International leaders in the field of TE recommend a research agenda that would address this deficiency. The TE profession needs to develop a clear understanding of the value of ESTE, provide conclusive evidence regarding the technological literacy outcomes students attain, and the unique benefits ESTE offers to children (Foster, 1997a; Foster, 1997b; Johnson and Liu, 2000; Wright, 1999; Zuga, 1997).

The following research question guided this study: What student technological literacy outcomes are related to the use of technology education activities and experiences? Gender differences related to the research question were also investigated.

Methods and Design

Subjects

This study was conducted in a suburban, elementary magnet school in the Midwestern United States. Subjects for this study were 20 fifth-grade students, 9 girls and 11 boys, ages 10 -11 years-old**,** identified with superior cognitive ability by state standards (i.e., gifted and talented), whose daily instruction was provided in a fifth-grade, self-contained elementary classroom. The curriculum in this classroom was interdisciplinary and integrated with an emphasis on problem-based learning strategies in mathematics, science, and technology. The students participated in specific ESTE activities and experiences throughout the academic school year. The teacher of the students is also the researcher/educator in the field of ESTE as well as a 15-year veteran teacher in gifted education, who has taught during those years within the described elementary classroom.

Methodology

This descriptive study employed a qualitative methodology to provide insight into understanding the value of ESTE activities and experiences in developing student technological literacy outcomes in the elementary classroom. Qualitative research can identify new issues and fresh insights with respect to ESTE teaching and learning practice (Fasse and Kolodner, 2000; Hoepfl, 1997; Lewis, 1999; Petrina, 1998; Rowell, 2001; Zuga, 1994). It is essential to get primary evidence from first-hand, on-site observations. With the shortage of researchers in technology education, teachers themselves can be a rich source of collaborative researchers to assist the field in furthering studies needed to examine the elements of technological literacy.
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The qualitative methods used in this study provided in-depth analysis based on “design experiment” in the classroom. Assuming that qualitative research has to be conducted in complex settings, particularly in developing effective curriculum materials, in a design experiment, qualitative researchers engineer an innovative educational environment to promote learning, while conducting experimental studies of those innovations (Kolodner, 2001). Focus group interviews and observations of student performance related to Technology Content Standards were used to collect data.

Focus Group Interviews

Using qualitative interview methods, students were asked to participate in focus group discussions related to robotics and ESTE activities and experiences at the end of the year in May, after they had engaged in ESTE. The conversations and dialogue were used to gain further insight and understanding of students' conceptual understanding of technology. Ten focus group interview questions were designed to produce open-ended discussion and reflections to address the research question as well as potential gender differences (see Table 1).

Table 1

Focus Group Interview Questions

1. What new technology skills do you have now that you have experienced robotics?
2. What aspects of technology are particularly good for girls? Boys?
3. Do you think this is the kind of technology program that should be available for you at your next grade level? If so, why? If not, why not?
4. Imagine that you were the teacher. How would you teach robotics differently?
5. Are there any new areas of science and technology in which you are more interested now that you have experienced robotics?
6. How would you describe a robotics program to students from other classes who don't know about the program?
7. Why do you think students should learn about robotic technology?
8. What is one important thing you learned from our robotics program that you think all students should learn?
9. What do you wonder about now after experiencing the robotics program?
10. After studying about robotics and society, what issues concern you?

Students were divided into two groups of 9 girls and 11 boys. Although the 20 students had participated in the technology education (TE) activities in three mixed-gendered teams, it was decided to collect this data using all girl and all boy groups. It was expected that the students would be freer to express their opinions without the social dynamics and influences related to the preteen years. The students at this age and at the school year's end were beginning to experience a high degree of awareness of and distraction by members of the opposite sex. The purpose of the design of the interviews was to eliminate the possibility of these distractions through the use of single-gender groups for gathering of information.

The focus group discussion was conducted first with the girls because it was convenient to do so, and then with the boys. Each group sat around a table with the researcher and a cassette tape recorder in the middle of the table. The students were informed of the goals to gather more information about their attitudes and perceptions related to the TE experiences and activities. The students were well aware of the research objectives and were eager to help with the research endeavor – and as always to express their opinions. Each focus group discussion took 1 ½ hours and was conducted in the classroom.

Focus group discussions were recorded on audiotapes. After recording the discussion, the tapes were transcribed as closely as possible to the original statements. However, some of the girls were soft-spoken and some words were indiscernible. Even though the gist of their statements could be inferred, the researcher refrained from "filling in the blanks." The data used were statements that were clearly heard. Pseudonyms were used to record and report data related to student responses.

A naturalistic approach to research emphasizes the constructive nature of the knowledge created through the interaction between the participants in interview conversations. The transcribed focus group interviews were examined to identify emerging patterns in pupils' conceptual understanding of technology related to TE activities and experiences. Qualitative procedures were used, including systematic coding and categorization, through content analysis supported by ethnographic summary (Morgan, 1988) to analyze student responses to the focus group interview questions.

One by one, the responses to each discussion question were examined, first for the girls and then for the boys. A content analysis of the responses revealed specific coding and categories which provided a means of sorting the descriptive data for main ideas and themes. A chart of the general ideas expressed in the responses of each focus group member was developed for each interview question. In that way, initial patterns in student responses could be determined. Analysis of preliminary patterns across all students as well as those specific to girls or boys were identified. This process was repeated a number of times to entertain potential alternative themes and patterns. Through this iterative process, specific themes and patterns were confirmed along with supportive direct quotations.

Observations of Student Performance Related to Technology Content Standards

The Observations of Student Performance Related to Technology Content Standards (OSP/TCS) was developed to identify student literacy outcomes related to the Technology Content Standards, and to develop a student profile of technological literacy developed during the ESTE activities and experiences. The profile chart lists the Technology Content Standards associated with each of the technology activities and experiences implemented in the classroom.

All students were observed during the activities to develop individual student profiles of technological literacy. Notes were made about student performance related to the Technology Content Standards (ITEA, 2000) during various activities. At the end of each TE activity, students were rated at a "novice" (N), "apprentice" (A), or a "researcher" (R) level of accomplishment which was interpreted as a beginning level (1 point), a developing level (2 points), and an accomplished level (3 points) relevant to their age range. Table 2 shows sample items from the OSP/TCS student profile. Scores on the student profiles were aggregated and averaged across students and by gender.

Table 2

Sample Items From the Student Profile, Observations of Student Performance Related to Technology Content Standards (OSP/TCS)

Technology Content Standards	Performance Level			Source of Evidence
	Novice	Apprentice	Researcher	
	1 point	2 points	3 Points	
The Nature of Technology				
1. Students will develop an understanding of the characteristics and scope of technology. 2. Students will develop an understanding of the core concepts of technology. 3. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.				Activity #2 – Robots Activity #6 - FIRST LEGO® League (FLL) 2003 Robotics Challenge CITY SIGHTS!

Context and Classroom Procedures

The curriculum for the students was constructed beginning with an alignment to the Midwestern school district's course of study, which was aligned to the State Academic Content Standards and the State Proficiency Learning Outcomes in English language arts, mathematics, science, and social studies. With these standards as a foundation, course work that was challenging, compacted, differentiated, problem-based, and enriched was designed.

The curriculum was planned to engage students in specific ESTE activities in which academic outcomes were integrated and related to students' everyday lives. Students were challenged to solve personally relevant, real-life problems to develop social awareness and concern as well as intellectual skills.

The curriculum in this ESTE program provided students with the opportunity to formulate an awareness of how their individual learning could have influence over their own environment and make a positive impact on society. The program was designed to develop student awareness and actively engage them in socially relevant situations, by identifying real-world problems; planning, designing, and developing solutions to them; and evaluating their implementation.

With standards in the forefront, the students and the teacher negotiated what to investigate, set learning goals, decided on problems to solve, and explored through new learning journeys.

Students examined the problem, researched its background, analyzed possible solutions, developed a proposal, and produced a final result. They participated in designing, creating, and evaluating their work. Students were encouraged to make choices so they could become strategic learners who learn how to learn. Student autonomy, drive, and collaboration were reflected in the language of their conversations.

In order to give an in-depth picture of student performance and progress toward the academic content standards, assessment consisted of classroom-level portfolio assessments that included open-ended tasks and constructed responses, performance tasks, informal assessments, and self-assessments and reflections. Instructional decisions were developed based on assessment data of what students know and are able to do, and was planned to meet individual student learning needs and enhance student strengths. Students in the classroom experienced performance-based assessment, which was ongoing and part of the instructional process to provide feedback for growth. Assessments provided information from which to develop future learning experiences; students were taught and encouraged to have a role in assessment of their progress and learning. The teacher guided the students to view content from multiple viewpoints and perspectives. Students were also assessed using mandated state and local standardized assessments.

Grouping was flexible within the classroom and organized around collaborative work according to specific instructional purposes. Groups were configured and reconfigured so that each student could work with different people. This flexibility allowed for both heterogeneous grouping as well as forming groups around common interests or needs. Cooperative learning strategies were used to give students experience in working together on a task of interest to them, placing them in simulated roles to portray a picture of the adult world and develop skills in communication.

The boundaries of the classroom were extended beyond the four walls of the classroom to include local, state, national, and international communities. Opportunities were planned for students to connect with the community and the larger world outside the classroom, to participate in the civic life of their community, to become better equipped to address socially pressing issues as adults. Local community members and parents were invited and actively involved in the classroom as partners in education to present their talents, experiences, expertise, hobbies, or other interests that would enhance the education of the students in the classroom.

Timeline for Technology Education Activities

TE instructional activities and experiences were selected to engage students in a variety of problem-based learning situations as part of their regular instructional program for approximately a 9-month period of time. The instructional activities were aligned with the Technology Content Standards. The specific standards are listed in Table 3.

Table 3

Technology Content Standards Related to TE Activities and Experiences

THE NATURE OF TECHNOLOGY
Standard 1: Students will develop an understanding of the characteristics and scope of technology. Standard 2: Students will develop an understanding of the core concepts of technology. Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
TECHNOLOGY AND SOCIETY
Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology. Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
DESIGN
Standard 8: Students will develop an understanding of the attributes of design. Standard 9: Students will develop an understanding of engineering design. Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
ABILITIES FOR A TECHNOLOGICAL WORLD
Standard 11: Students will develop the abilities to apply the design process. Standard 12: Students will develop the abilities to use and maintain technological products and systems. Standard 13: Students will develop the abilities to assess the impact of products and systems.
THE DESIGNED WORLD
Standard 16: Students will develop an understanding of and be able to select and use energy and power technologies. Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies. Standard 19: Students will develop an understanding of and be able to select and use manufacturing technologies.

Activity #1- LEGO DACTA® sets – Month of September. LEGO DACTA® Gear Set #9610 (The LEGO Group, 1997a), the LEGO DACTA® Pulley Set #9614 (The LEGO Group, 1997b), and the LEGO DACTA® Lever Set #9612 (The LEGO Group, 1997c). Working with partners, students explored the concepts of simple machines, investigated the principles and main ideas behind the concepts, and solved simple extension problems. technology education objectives of these investigations relate to Design: Standards 8, 9, and 10 and The Designed World: Standard 16.

Activity #2 – Robots - 2 days. In the next activity, students viewed the video *Robots* (A&E Television Networks, 2001) produced for The History Channel® Where the Past Comes Alive™. They examined and discussed the multiple uses of robots from the past to the present, and envisioned future uses. The Technology Content Standards related to the video and class discussions were: The Nature of Technology (Standards 1, 2, and 3); Technology and Society

(Standards 4 and 6); Design (Standards 8, 9, and 10); and Abilities for a Technological World (Standard 13).

Activity #3 - Robotics in the Classroom: A Collaborative Unit for 5th and 6th Grade Students in Science, Math, and Language Arts (Wright Patterson Air Force Base Educational Outreach Office [WPAFB], 2001) – Month of October.   The WPAFB curriculum was used to further introduce the students to the development of robotics and the prevalence of robotic technology in today's world, targeting Design (Standards 8, 9, and 10) and Abilities for a Designed World (Standards 11, 12, and 13). The curriculum focus is on the history and uses of robots, the components of robots, and the design of robots; and leads students to a transfer activity (in this case, LEGO® MINDSTORMS™ Robotics Invention System™, The LEGO Group, 2000) in which students apply what they learned to real-world problems by designing, building, and programming their own robot to accomplish designated tasks.

Activity #4 - Forming engineering teams - 2 days. Students participated in team-building activities. Three teams were formed (two teams of 7 students and one team of 6 students).

Activity #5 - LEGO® MINDSTORMS™ Robotics Invention System™ - Months of October and November. After the completion of the first three sets of activities, students were ready to apply their knowledge in a transfer activity. The LEGO® MINDSTORMS™ Robotics Invention System™ was selected to align with Abilities in a Technological World: Standards 11, 12, and 13. Using the RCX™ programmable microcomputer Lego brick, students create, modify, and download computer programs to robots that gather sensory information, can learn from their environment, and prioritize their actions. To expand upon the material previously learned, students were given the chance to build and program their own robots to perform specific tasks.

Activity #6 - FIRST LEGO® League Robotics Challenge: CITY SIGHTS! – Months of November through December. The FIRST LEGO® League (FLL) Robotics Challenge is an educational program sponsored jointly by the organization For Inspiration and Recognition of Science and Technology (FIRST) of Manchester, NH and the LEGO® Company. With the FIRST LEGO® League Robotics Challenge, the students had the opportunity to see how the concepts and ideas they learned connected to real-world problems and solutions (The Nature of Technology: Standards 1, 2, and 3 and Technology and Society: Standards 4 and 6).

The FLL program creates a learning environment that brings with it the excitement of building a robot that is applicable to real-world situations. Competitions are organized throughout the United States and countries around the world. As students master teamwork dynamics and problem solving, they design, construct, program, and test fully autonomous robots (Design Standards 8, 9, and10). Students are immersed in an atmosphere in which they can explore their own ways of approaching science, mathematics, and technology in positive and non-threatening ways (The Designed World: Standards 16, 17, and 19).

Each year, FLL teams face a complex scenario that requires them to use robotics design to overcome a series of challenges much like those facing society today. The research for this study was conducted during the 2003 challenge, CITY SIGHTS! The FLL 2003 Challenge: CITY SIGHTS! has two main parts: (a) the robot performance part in which students design, develop, and program an autonomous robot device that can perform more than one task, solve the missions of the challenge, and is capable of assisting the city planners and employees. Students built and programmed their robots to direct them through the challenge course of CITY SIGHTS! This performance required students to combine elementary computer programming, mechanical design, strategy, and sportsmanship; (b) the research assignment in which each team has to give a detailed research presentation to a panel of judges that demonstrates the team's ability to analyze problems in providing basic services to the inhabitants of the city, consider the variables and factors such as population, finite land and water resources, and unique geographical situations, propose new workable robotic technology solutions to meet the needs of the inhabitants of different cities around the world, and create a presentation of their research findings and conclusions. (Design: Standards 8, 9, and 10 and Abilities for a Designed World: Standards 11, 12, and 13).

For example, one team designed "frogbots" that would test the water quality of their city to detect possible contaminants that may enter the water supply. The "frogbots" could warn the city of terrorists who might try to sabotage our water supply. Another team designed a robot that could screen travelers and baggage entering the Los Angeles airport or the shipping docks. One team created a robot for the homeless in Paris that could inform them in several languages where food, clothing, shelter, and jobs existed that could assist them.

Activity #7 – Tournaments for the FLL 2003 Challenge: CITY SIGHTS! - December and March. The FIRST LEGO League challenge season culminated as teams came together to celebrate Robot design and performance, teamwork, sportsmanship, and documented research -- the criteria judges used to determine award winners and present trophies that signify team technical and performance excellence. The teams made creative presentations of their research, technical knowledge, and robotic solutions through skits, written plays, formal reports, displays, and power point presentations (The Designed World: Standards 16, 17, and 19).

Activity #8 - Guest Speakers and Engineers – Months of October to December, and the month of March. Visiting scientists, engineers and city managers, and community members provided mentorship and support for the robotics teams as they prepared detailed research presentations about urban problems. Local municipal planners, such as the City Electric Utility Manager, the City Water Utility Manager, and the City Community Planner, visited the class and described their jobs, discussed water and electric conservation, and considered alternative energy sources with the students. Engineers worked with the students on the engineering design process, the technical tasks, and programming (Design: Standards 8, 9, and 10 and Abilities for a Designed World: Standards 11, 12, and 13).

Activity #9 - Children's Engineering and Design Exhibition: A Showcase and Celebration of Technological Accomplishments in the FIRST/LEGO® League Robotics Challenge IV: CITY SIGHTS! (FIRST/LEGO® League, 2002) – Month of May. Teachers at the school were invited to bring their students to see an exhibition of CITY SIGHTS! including the robot performance and the research presentations. Parents, relatives, and community members were invited to the showcase in the evening.

Results

Focus Group Interviews

Student responses in the focus group interviews were subjected to content analysis, systematic coding, and categorization. Using an iterative process, three main themes emerged related to technology education: (a) gender roles, (b) gender and work habits, and (c) student literacy outcomes. Each of these themes were supported by direct quotes from students (ethnographic summary.) Patterns in the focus group discussions reflected the nature of focus group interview methods. That is, students picked up on one another's comments, sometimes echoing their responses, extending them, or building upon remarks.

Technology Education: Gender Roles

The girls indicated that they wanted to have new chances and opportunities related to technology education. Many of the girls saw themselves as capable of and interested in learning technology. They did not express a stereotypical view about girls and their inability to do technology. For example, Regan reflected this perception at various times during the focus group interview.

I learned how to program more this year. . . . And I think I learned a lot more about how the gearing -- just how things work. I think I like programming.

This perception was echoed at various times during the focus group interview. Some girls mentioned they were reluctant and less confident in their own abilities regarding technology, however, and often times shut down and backed down when boys became assertive.

In contrast, typical gender stereotypes and roles related to technology were noted in the conversations of the boys. They agreed that boys have more opportunities at an earlier age to build and construct and use technology in their home environment. Their toys include building blocks, construction toys, video games, and computer games. For example, Sam articulated this perception.

. . . like you don't see many girls getting a LEGO® – a 10,000 piece LEGO® thing for their birthday, but you see tons of boys asking, "Oh, I want this LEGO® thing," because they have the patience and time to take days or weeks to build something. And girls don't have, I think, the patience to do something like that.

Conversations with the boys revealed that many thought girls were not suited for technology education activities, except for the research part. They expressed that girls were too concerned about how they would appear. Boys also perceived that girls are afraid to make mistakes. They thought girls had difficulty taking risks for fear of failure and were concerned how they would appear to others if they failed.

Girls believed boys would rather work on their own, preferred to do things their own way, would not ask for help, and have an "all or none" attitude. Their perception was that girls were open to boys' ideas, but not vice versa. Boys thought girls don't want to understand how things work, but that girls should be provided with technology opportunities. They thought that girls really aren't interested and don't want to learn technology. The consensus was that maybe there is hope for the girls, if they are immersed in technology; then, they would get interested in it.

Technology Education: Gender and Work Habits

Work habits such as patience, perseverance, and teamwork surfaced often during the discussions with both girls and boys. However, their perceptions were completely contradictory. Each gender attributed positive attributes to their own gender and negative attributes to the other gender. Many of the girls brought up the work habit issue of perseverance when working on technology education activities. The girls perceived boys as being less persevering and patient, especially when changing individual variables and taking incremental steps. They said boys keep starting over from scratch instead of changing and improving one thing at a time. Girls saw themselves as better able to troubleshoot and fix problems, and as having more common sense and patience than boys. They said girls get less frustrated and are better organized. Regan expressed this idea,

One thing – well I also learned never give up and you really have to have perseverance. But one thing I learned was that even if something goes wrong -- something could always happen and you can always fix it, and it’s not about everything being perfect. And it’s not about winning, but it’s about doing the best you can do.

Contrary to what the girls perceived, the boys said that they have many more ideas than girls did, more perseverance and patience to stick to something, and that girls have no patience. Boys perceived themselves as having more perseverance than the girls. The boys expressed that they often had to redo the girls’ work since girls don't try to fix their work or have the patience to correct their problems. The boys felt that they had the drive to implement their ideas whereas girls did not. Boys complained that girls won't listen to boys, “who know how,” but boys will listen to girls. For instance, Stephen thought boys have more perseverance

. . . and *tolerance* for not doing something right the first time. Like Michael worked on his program for *six months* I think until he figured it out right. He worked on it from November to the end of May until it finally worked, yet he like never got totally – I mean trust me – I mean he was frustrated that he couldn’t test it out on our robot all the time, but he kept with his program. And he wasn’t frustrated that it didn’t work the first, second, and thirtieth times . . . sometimes boys have a little bit more patience . . . when they (girls) build something and it doesn’t work, sometimes they don’t throw it away, but yet they don’t really try to fix it. . . . And then sometimes when a boy . . . tries to tell them – show them help – ‘cause they know how they can fix it, they won’t take it because it’s a boy that’s giving them the advice.

The issue of teamwork was mentioned many times by the girls and infrequently by the boys. Girls thought they were more inclined to work well in cooperative groups than boys. The girls wanted to work toward developing better teamwork skills, such as how to come to a consensus of opinion and how to develop their own ideas, while still working cooperatively in a team. With confirmation from each other, several girls expressed this general perception. Amy reflected, What I learned is when you have an idea you have to learn how to cope with it and develop it to make it work while working in a team.

Technology Education: Student Literacy Outcomes

Several indicators of student literacy outcomes associated with technology education were noted consistently throughout the dialogue of both the girls and the boys. Many students elaborated on problem solving, research, connections to mathematics and science, and teamwork.

The dialogue seemed to naturally group around specific technology literacy outcomes as expressed in the Technology Content Standards. This could have been due to the type of questions asked in the focus group interviews or the nature of the instruction in the classroom. Consequently, the findings are presented as they relate to the Technology Content Standards. However, the Standards at times, overlap and are not easily separated. In particular, student comments often merged in relation to The Nature of Technology (Standards 1, 2, & 3), Technology and Society (Standards 4 & 6), and Abilities for a Technological World (Standards 11, 12, & 13,). Words and phrases from the standards were used to guide the analysis of student responses generated in the focus group interviews. These are included to assist the reader in understanding the relationship of student comments to technological literacy outcomes.

Key ideas used to guide the analysis related to The Nature of Technology (Standards 1, 2, & 3) include: (a) characteristics and scope of technology, (b) core concepts of technology, and (c) connections to other subjects. Students expressed that they valued technology education activities and experiences because they extended their knowledge and understanding about the nature of technology and transferred to personally relevant real-life situations. For example, Alyssa stated,

I think you should do robotics because today . . . in our world a lot of things are surrounded by technology and all the greatest discoveries are mostly in technology. And when we grow up it's probably going to be most of what the world is. It's mostly going to be technology 'cause now the older ways of doing things like writing letters and sending them in the mail is really fading out and instead we use computers to send emails.

Both girls and boys were curious and wanted to continue to learn more about "how things work," such as how infra red signals work, how motors work, how a computer works, and how programming controls a robot's actions.

The Nature of Technology Standards includes an awareness of technology careers. Students expressed an eagerness to keep learning and some had planned to attend summer technology camps to learn more about computer language and programming. Several students shared that they were thinking about their future careers, and were more interested in all areas of science and careers in robotics technology. Boys expressed a growing interest in various career fields related to technology such as architecture, building and construction, and neurology. Sam shared his interests "in building robotics and programming things." Alan noted, ". . . because I've done robotics, I want to do building more . . . construction." After working with the LEGO MINDSTORMS® RCX (The LEGO® Group, 2000) programmable brick, the "brain" of the robot, Nicholas was interested in a career in the neurosciences. Specifically, he said he was interested in “neurology.” Several students indicated confidence in their abilities to pursue difficult careers and attend high ranking universities. For example, Jarrod discussed his current hope to attend a particular university, “Stanford.”

Many of the students made connections between technology, science, and mathematics bringing coherency and relevancy to the curriculum. Several students expressed the relationship between the technology activities and experiences in the classroom and future career opportunities. Several students offered that robotics technology education should be available in elementary school because it seemed to help them with problem solving, science, math, and other subject areas. For instance, Amy offered,

I think you should teach robotics because it does teach them science and math and science and math will help you when you go to find a job. And if you’re not introduced to robotics, they might be good at it, and they don’t know it and then if they do know they’re good at it, they might want a job in it.

Key ideas used to guide the analysis related to Technology and Society (Standards 4 & 6) include: (a) understanding of the cultural, social, economic, and political effects of technology and (b) understanding of the role of society in the development and use of technology. Involvement in TE activities increased student awareness of the impact of technology on society. They indicated an awareness of history, innovation, and invention and demonstrated a growing awareness of societal needs in the larger, global community after conducting research for the FLL Challenge CITY SIGHTS! Students expressed concern for the impact of technology on people in society, reflecting awareness and concern for the safety of people in communities.

How society will deal with robots of the future seemed to big a concern to all students, noting the efforts to create robots with human characteristics and expressions of feelings, Several students shared their thoughts about human-like robots, focusing on possible ethical questions that might be involved with robotic technology. Ethical issues continued to surface in discussions with both the girls and the boys indicating similar concerns about the future of robotic technology. For example, Regan thought,

. . . robotics can help people but I personally don’t think society is ready for it. You know, they’re so used to humans being on top and nothing comparing to humans and everything. And you know, if you suddenly have this technological thing that’s up there right along with you, you know, I don’t think we’re prepared for that – emotionally . . . . I’m not so concerned about how smart they’re going to get. I don’t think they are going to take over the world or anything, but I guess I’m worried about how society feels.

Alyssa added her thoughts about human-like robots focusing on possible ethical questions that might be involved with robotic technology.

On the movie we watched last night, *Robosapiens*, they had this little robot. Well they had a couple of them. One’s called Kismet, who they’re trying to give a personality to, and they said like “Where’s Kismet?” And they’re trying to get the emotions into the robot, you know . . . . So it's like there's a lot of issues we have to think about . . . but one thing they showed was this little bitty robot . . . He was cute . . . and the lady said "Come on now it's time to go to bed . . . and he said "I don't want to go to bed!" And she picked him up and turned him off, put him in a sleeping bag, and zipped the bag, and said, "That's one thing you can't do with a human child!" I guess the idea is that eventually . . . if the robot's small, I mean what are you going to do? Turn it off? . . . but if you turn it off . . . it's like a little human . . . . If you make a bunch of robots that think for themselves . . . you know it's like mass production of humans.

Student conversations revealed a developing ability to access the impact of products and systems. Students expressed a growing awareness that they could make an impact on society with their own learning. Students indicated a desire to learn more about robot technology to address larger societal and environment concerns such as global warming. Alyssa reflected her interest in addressing larger societal concerns,

. . . I would like to learn how to . . . make an actual robot move and . . . help it help with the world [problems]. Like with oil spills, you could design some kind of robot that could go out and like be magnetic to oil or something like that.

Key ideas used to guide the analysis related to Design (Standards 8, 9, & 10) include: (a) understanding of the attributes of design; (b) understanding of engineering design; (c) understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving; and (d) higher level thinking, problem solving, intellectual processes, and troubleshooting abilities.

Student responses indicated an understanding of aspects of the design process; the role of problem finding, research, planning, invention, and innovation; building and programming; testing and evaluating solutions; and presenting working solutions. With better "how to" skills, they learned to troubleshoot problems as they occurred. Student responses reflected a sense of confidence in their ability to understand and use technology. Students indicated using higher level thought processes, such as analysis and evaluation as they worked through problems and solutions. Jessica reflected this understanding,

I learned how to program and how to analyze and test the robots and programs and adjust the programming . . . . I knew after I figured out what was wrong with one thing I didn't have to write another whole program. I learned not to do that.

Students reported that they developed abilities to apply the design process and to use, maintain, and access products and systems. They indicated an understanding of design processes and concepts, mentioning the importance of accuracy and precise attention to details, and documenting and recording processes so they could be repeated. Students discussed the responsibility involved in building structurally-sound safe objects for users of technology. For example, Alan discussed,

. . . when we build . . . [we have to] weigh it . . . [we are] responsible for lives . . . one loose screw . . . [can cause problems] . . . like on the Columbia.

Students expressed having better problem-solving strategies after experiencing technology activities and experiences enabling them to use ideas to create solutions to problems. Girls and boys both indicated that they better understood technology concepts or “how things work,” and were able to identify and solve problems using mathematics and science knowledge. For example, Nicholas discussed the use of science and mathematics to build, calculate, program, and solve problems required in using rotation sensors on the robots.

I learned more about the gears, pulleys, and levers and how to use ideas to create a solution . . . . I liked (figuring out) the robot’s (wheel) circumference a lot.

Key ideas used to guide the analysis related to Abilities for a Technological World (Standards 11, 12, & 13) include: (a) understanding the attributes of design; (b) ability to apply the engineering design process and procedures; (c) ability to research and develop projects and systems; (d) ability to develop, use, and maintain technological products and systems; (e) attitudes, motivation, and personal interest in learning; (f) ability to reconstruct or adapt to society; (g) teaming ability; (h) success work behaviors; (i) skills and interaction with peers; and (j) abilities such as programming and construction.

Students discussed the abilities they have and will need in the technological world of the 21st century and the relevance of technology to individuals in society. They believed technology to be both personally and academically relevant to their own lives. Jessica thought about careers,

Because when you’re an adult you have you get to choose the jobs you work in. And if you like and if you’re interested in robotics and you like technology, then you might want to go into a technology career later on in life.

Students talked positively about their technical abilities such as programming and construction abilities. They said, as students, they need the challenge technology presents and recommended that it should be taught in their subsequent school years. Several students expressed the value of technology education activities and experiences in relation to learning other subjects such as mathematics and science, and in fostering necessary social skills like teamwork, perseverance, and respect for other people’s ideas. Michael said,

. . . it [math and science] won’t be that hard if you do robotics because the gears and rotation sensors, you have to do all the math of all the gears you have attached to your motor and stuff.

Reflecting on the value of technology education activities, students mentioned that as they learned more skills and concepts in technology it reduced fear and apprehension of the unknown. Jessica expressed,

I think it [technology education activities and experiences] should be offered because it really is a great thing because people are still scared of robots. They’re so afraid that the robots will take over. Now that we know we have control over them, we have less fear and it’s really for the good of everyone.

Several students mentioned the value of learning technology early so that people in society will have a better understanding of technology as adults. Nicholas reflected,

I think it's good because you learn more and you get more advanced in it. And it offers goals and opportunities and if something goes wrong you can come up with something, like invent something on the spot, or like make something like a pulley or something. You get more knowledge and skills and concepts.

Students talked positively about their technical abilities such as programming and construction abilities. They said, as students, they need the challenge technology presents and recommended that it should be taught in their subsequent school years. Many students expressed that they wanted to continue doing robotics the following year. Alyssa articulated this idea,

I think there should be . . . robotics next year because it's a lot of work. And after you've been doing it for a long time, and then they change it [each year's FLL robotics challenge] then you can still profit from it even more . . . . You also learn other things like science and math because like you use math to figure out how the robot moves . . . . You learn lots of things about science and technology, but you learn about working together. You learn about working as a team. You learn about accepting different ideas besides your own. So I think you learn about a lot of different things, not just about robotics. Everybody needs to learn stuff like that . . . . I learned about how to research better and about how the homeless live.

Key ideas used to guide the analysis related to The Designed World (Standards 16, 17, & 19) include: (a) develop understanding and ability to select and use energy and power technologies, (b) develop understanding and ability to select and use information and communication technologies, and (c) develop understanding and ability to select and use manufacturing technologies. Students indicated a better understanding of and ability to use information and communication technologies after having experienced TE activities. Students explained their understanding of technology and the ability to do technology in terms of their own experiences mentioning identifying a problem then designing and developing solutions. Stephen explained,

I'm a lot better at working with computers. I used to be one of those kids that looked at the keyboard and I didn't know anything about computers and I always thought that the job I wanted, I never wanted to see a computer ever . . . . And now actually, I've decided that I, umm, don't write reports anymore, I sorta had rough drafts . . . . [I would] write a rough draft and then do it on the computer, where I couldn't write my rough draft on the computer. Now I can just sit down and type . . . . I think I've learned a lot about like how to troubleshoot things like when the computer freezes up.

Students often expressed their concern that society needs to better understand technology, particularly the use of robotics technology, as a mean to improving the human condition, make life easier with more inventions and have a better, more stable world. Frank reflected this concern,

. . . I think in this ever-changing world, we're using robotics technology more and more so if the students keep coming out of their education without knowing anything about robotics technology, they would not know as much about the world because we're using the robotics technology more and more.

Observations of Student Performance Related to Technology Content Standards

Students were observed during all technology education activities and experiences during a period of six months. The profile of each student was recorded on the Observations of Student Performance Related to Technology Education Standards, a profile developed by the researcher. Each activity and experience was coded to the Technology Content Standards and students were rated novice, apprentice, or researcher. The scores for each standard were averaged for all students and by gender. Figure 1 shows the results for each Technology Content Standard for all students.

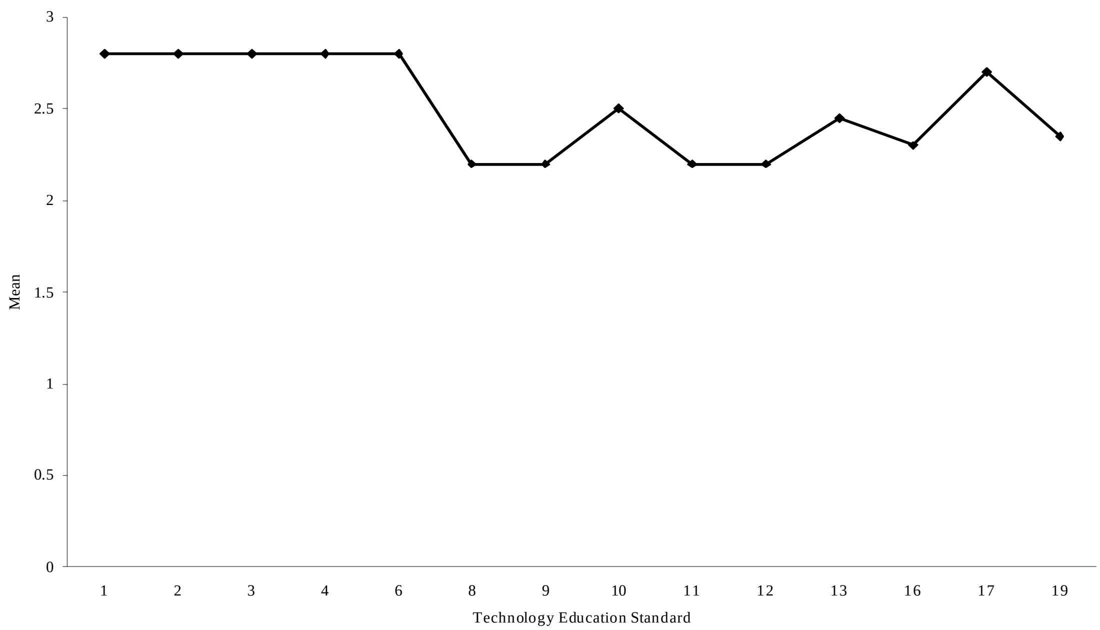

Figure 1. Student performance profiles related to the technology content standards following technology education activities.

Figure 1 indicates that most students were excelling in performance related to Technology Content Standards 1 through 4, 6, 10, 13, and 17. Standards 1 to 3 deal with The Nature of Technology and states:

Standard 1: Students will develop an understanding of the characteristics and scope of technology.
Standard 2: Students will develop an understanding of the core concepts of technology.
Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Standards 4 and 6 deal with Technology and Society and states:

Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
Standard 6: Students will develop an understanding of the role of society in the development and use of technology.

Standard 10 deals with Design and states:
Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Standard 13 deals with the Abilities of a Technological World and states:

Standard 13: Students will develop abilities to assess the impact of products and systems.

Standard 17 deals with The Designed World and states:

Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.

A similar pattern with regard to the Technology Content Standards was observed for girls, but not the boys (see Figure 2).

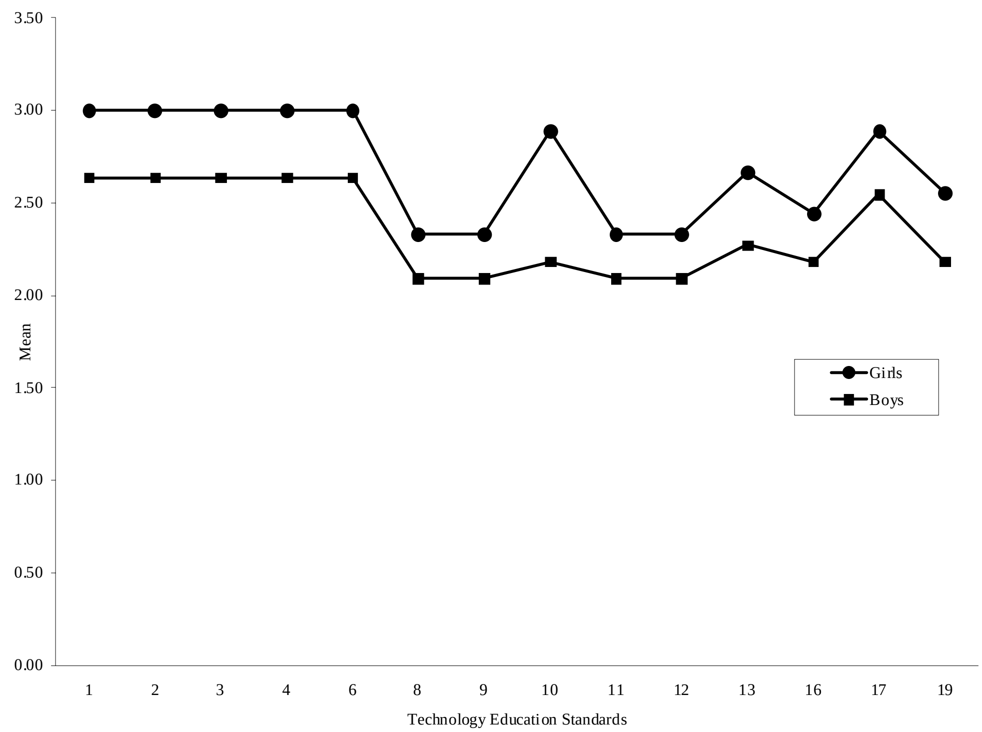

Figure 2. Student performance profiles related to the technology content standards following technology education activities by gender.

Conclusions and Discussion

Based upon the focus group interviews, it appears that only the girls who engaged in ESTE activities and experiences perceived to a greater degree that girls were equally capable of participating in technology as boys. These girls expressed knowledge of technology along with a willingness and capability to participate in technology. They felt that ESTE provided an opportunity for them to advance and take risks. In contrast, boys who engaged in ESTE activities and experiences were reluctant to recognize the equal role of girls in technology. They perceived in the girls, a lack of experience and suitability for technological activities, other than to do research. Boys held stereotypical views about roles of girls in technology.

Other gender issues surfaced related to the ability to do technology. For example, girls perceived that they were better able to work in teams to do technology than boys. Interestingly, girls perceived girls to be more perseverant during technology activities while boys perceived boys to be more perseverant. Clearly, the girls and boys have a different perspective on the role of girls to do technology. Similar to the results of both Bame et al. (1993) and Boser et al. (1998), the current study found girls to have more positive attitudes and perceptions related to girls' knowledge of and ability to do technology. However, the boys in the current study seemed to maintain a more stereotypical view of the role of girls in technology.

It was evident in the focus group discussions that all students valued the ESTE activities and experiences that they felt extended their understanding of technology and were academically and personally relevant. They also valued ESTE activities because they enabled them to move beyond their own situation and community. Moreover, they recognized the benefits of ESTE activities and experiences in terms of future careers. They particularly valued their ability to make a positive impact on society and societal problems as a result of their knowledge and skills gained from their ESTE activities and experiences. However, they expressed concern about the impact of technology on society and recognized that the impact could be negative as well as positive. Perhaps, this critical eye influenced the lessening of their value of technology.

When Raat and de Vries (1985) developed the PATT, they investigated students' attitudes toward and conceptual understanding of technology. Their results suggested that girls see technology as less important than boys. Boser et al. (1998) indicated that after using the integrated approach, there was a negative change in attitudes toward technology. The authors explained that perhaps students had achieved a more balanced view of technology. Students retained a more positive outlook toward technology when they participated in less controversial content. The results from their study suggest that perhaps at the beginning of the integrated approach, students underestimated the complexity of technology with its potential for both positive and negative consequences. In the current study, similar results are suggested. Perhaps the gifted and talented fifth-grade students who engaged in ESTE activities and experiences, particularly boys, began to see technology with a more critical eye, as they learned to assess the impact of technology on society and the environment in terms of both benefits and detriments. However, these same students expressed more positive attitudes and perceptions related to the value of technology compared to students without ESTE activities and experiences.

The focus group interviews and the Observations of Students based on the Technology Content Standards are the bases for understanding the development of technology literacy outcomes.

Both the girls and the boys who engaged in ESTE activities and experiences recognized the intellect and knowledge necessary to do technology. They identified knowledge and skills related to problem solving, mathematics and science, and interpersonal and teamwork skills as integral to the ability to do technology.

In the current study, student profiles were examined in regard to specific technological literacy outcomes as defined by the Technology Content Standards developed by ITEA. All students, particularly girls, demonstrated proficiency in the targeted Technology Content Standards for The Nature of Technology, Technology and Society, Design, Abilities for a Technological World, and The Designed World.

Students demonstrated understanding of the nature of technology as they identified key features of technology, including problem solving, programming, connections to mathematics and science, and teamwork. Throughout their conversations, students recognized the role of society in the development and use of technology. In particular, students expressed concern for the impact of technology on society. Students developed an understanding of the design process as they learned what a designer or engineer must consider as s/he develops and evaluates the usefulness of a new product or system. Students applied the design process to design innovations and solutions that met the criteria of the robotics challenge. Lastly, throughout the design process, students used information and communication technologies effectively.

Implications and Future Research

The results of the current study have several implications for the curriculum and instructional strategies for ESTE. Additional technology education activities and experiences need to be developed or selected that would increase student proficiency in specific Technology Content Standards, for example, the design process. Different grouping strategies based upon same gender and/or mixed gender need to be utilized. Additional equipment is preferable so that more students can spend time designing, investigating, and evaluating their own ideas and innovations to share with their team. It would be beneficial to spend additional time and use more activities to develop teamwork, interpersonal skills, group skills, and work ethic. More connections can be made to specific academic content standards in mathematics and science. Additionally, it would be beneficial to explore ways to tie language arts and social studies content standards to technology education activities and experiences. Strategies to incorporate technology education as connected to the academic content standards, rather than as an add-on to the regular curriculum, particularly for the self contained, elementary classroom, would be beneficial.

The implications for classroom practice derived from this study generated additional research questions related to the implementation of ESTE activities and experiences for the general elementary school population. For example, (a) Is there a difference in the development of technological literacy outcomes for students with different ability levels? (b) Is there a difference in the development of technological literacy outcomes for students in different grade levels? (c) Is there a difference in the development of technological literacy outcomes for students in same-gender groups compared to mixed-gender groups for technology education activities? and (d) Are there gender differences in the development of technological literacy outcomes for students based upon gender groupings?

This study clearly has served to enlighten the researcher/teacher about her own teaching practice. It provides suggestions for ESTE praxis for gifted and talented students. This study, along with future research, may assist teachers and curriculum developers in the design, selection, and implementation of technology-based instructional activities to promote technological literacy in all students.

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