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ABSTRACT

This paper reports the results of a qualitative study focusing on the ways in which technological tools are implemented in mathematics education in a Title I K-5 school. Specifically, the intent was to understand the perspectives and actions of the school's mathematics specialist and the multi-graded 2nd and 3rd-grade classroom teacher as they attempted to deliver instruction with technology for both English-as-a-Second Language (ESL) and non-ESL students. Results of the study have implications for school policy and practice regarding the role of English in the use of technology for the education of recently arrived non-English speaking children. The most important implication is that the classroom teacher/instructional technologist must take into account the role of language when designing and delivering mathematics instruction and technology to such students by ensuring students understand the academic instructions that are used in combination with the notational systems, and that the emphasis in discourse is that of "communication," instead of "verbal English." (Contains 18 references.) (AEF)

Lanuage as Access to Mathematics Learning and Technology in a Title 1 School

By. Tirupalavanam G. Ganesh & James A. Middleton

Language as access to mathematics learning and technology in a Title I school

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Abstract

This manuscript reports the results of a qualitative study focusing on the ways in which technological tools are implemented specifically in mathematics education in a Title I school. Specifically, the intent was to understand the perspectives and actions of the school's mathematics specialist and the multi-graded 2nd-3rd-grade classroom teacher as they attempted to deliver instruction with technology for both English as a Second Language (ESL) and non-ESL students. Results showed that a critical factor in access to mathematics education and technology for immersion students in a multi-graded 2-3 classroom in a Title I K-5 school setting is *language.*

Language as access to mathematics learning and technology in a Title I school

Introduction

In recent years, education technology has been infused into our nation's schools with the hope that it will improve the academic performance of our students (*Education Week*, October 1, 1998). Wenglinsky, (1998), presents findings from a national study (1996 National Assessment of Educational Progress in mathematics) of the relationship between different uses of educational technology and various educational outcomes. Reading literature on educational technology and media reports on this matter, a number of questions came to mind: How do teachers define technology? What does technology mean to the people in the school setting? What does the use of technology in mathematics education look like? In November, 1998, we embarked on a qualitative study to understand the use of technology in the mathematics education process in an Arizona Title I K-5 school. Interviews with the school's mathematics specialist, classroom teachers, observation in the classroom and Higher Order Thinking Skills (HOTS) laboratory and analysis of documents were used to gain an understanding of what is happening at the site.

With the publication of the National Educational Technology Standards for Students (ISTE, 2000), and the revision of the National Council of Teachers of Mathematics' (2000) *Principles and Standards for School Mathematics* coinciding in time, new emphasis has been placed on the importance of implementing powerful learning technologies into the mathematics classroom. The technology exists to allow children, even very young children, to explore complex and advanced mathematical topics, keep track of their learning histories, and represent their thinking in varied and complementary forms (NCTM, 2000). Implementation of such powerful tools, contrary to the perspective of popular culture, places firm emphasis on the role of the teacher in facilitating and channelizing students' activity to develop in a mathematically sound and sophisticated manner.

Calculators are ubiquitous. Computers and hand-held devices are following suit. In addition, new models of technology delivery are being instituted that make use of projection systems, local area networks and features of the world-wide-web, such that all students in a mathematics class can interact with technologies significantly, everyday—even when the ratio of computers to students is low (Middleton, Flores, & Knaupp, 1997).

The technology exists. Access is available. Exemplary practices have been identified. So, what is happening? At a gross level, we know that technologies are implemented differentially across grades and socioeconomic status of schools. However, within a

classroom, we have few analytic models of how teachers come to develop practices that make use of technological tools, and how those practices impact the learning of students. What constitutes "typical" implementation of computational media in a public mathematics classroom? How are technologies used as tools for deep mathematical understanding? This study was conducted to provide an analytic frame for understanding this question.

Methods of the Study

The study is situated within an interpretivist perspective (Erickson, 1986). Data was collected over a period of six months. The first author of this research report conducted the participant observations and the second author assisted the former with the data record keeping, methods of interviewing, analysis, and construction of the research report. Sources consisted of multiple **observations** of the classroom, computer lab and English as a Second Language (pull-out) classroom; **interviews** with the mathematics specialist, the classroom teacher, and the ESL and reading specialists; and **analysis** of curriculum and assessment documents.

Participant Observations

Over 30 hours (1 hour per day, twice per week, for 15 weeks) were spent observing the interactions in the classroom, the computer lab, and the ESL classroom. Under the assumption that the primary purpose of computational media in the mathematics classroom is to provide multiple ways of communicating ideas, exploring claims, and articulating arguments (Piburn & Middleton, 1998), the aim for each observation was to capture the classroom discourse as it pertained to these issues. The features of the discourse noted during observations were: 1) Technological tools used; 2) Mathematical Representations developed; 3) Arguments made (by students); and 4) Teacher Facilitation. To capture the relationship between arguments made and teacher facilitation, the teacher was audio taped continuously to obtain a verbatim record of her directions and interactions with students. These tapes were transcribed and integrated with the observation notes.

Teacher Interviews

Semi-structured teacher interviews were geared towards gaining an understanding of each teacher's philosophy and practice related to technology for mathematics instruction. Open ended statements, questions such as, "Please share with me information about your classroom. What are the school and district goals for mathematics? Please share definitions of technology. How do you envision the use of such technology in the classroom?" and so on were posed. Prompts were used to get access to the

teachers' perceptions. The classroom teacher, the mathematics specialist, the ESL teacher, and the reading teacher were interviewed at intervals of two-three weeks over the course of the study. Interviews lasted approximately thirty minutes each and were audio taped and transcribed.

Document Collection

Since technologies function as tools among other tools and materials that facilitate instruction, to understand this context, we collected artifacts from the district, school, teacher, and student levels. The materials we collected included curriculum materials such as the grade level thematic units, the district's curriculum with district articulated learner outcomes for mathematics, model math lessons, assessments, and related scoring guides. District-compiled assessment results (the 1998 Stanford achievement test), state academic standards, Fauna's assessment plan and school goals were collected. Student-generated work, sheets of paper used by students to work out mathematics problems, sample worksheets that were assigned as homework, and class hand-outs were collected as well. In addition, user manuals and teacher guides for software used by these students were made available to the researchers, as well as printouts of screen dumps and student work on computers.

Analysis of this data began with the most local context: Student work, handouts and curriculum materials to provide the substrate within which student and teacher discourse developed and around which the discourse revolved. School and district-level materials were used subsequently to provide an understanding of the barriers to technological implementation and the dilemmas faced by the teachers in supporting student learning through technology.

Analysis of Data

As the observations and interviews progressed, initial hypotheses about the role of technology in the plans and practices of teachers were noted. As regularities among the ways in which technologies were used, and the ways in which teachers and students discussed mathematics using technology-afforded environments and representations allowed us to induce firm hypotheses concerning *why* these patterns existed in this particular context.

A number of propositional assertions regarding the induced hypotheses were developed after a thorough reading of the entire data record. From this reading and the initial questions with which the study began, two assertions that were supported empirically survived the subsequent search for disconfirming evidence. In the results of this manuscript, these assertions are

presented with evidentiary samples that embody the data corpus. These samples are in the form of quotations from teachers and students, descriptions of teaching methods, classroom interactions from the observations, excerpts from teacher interviews, and descriptions of classroom structure.

The Setting

Fauna offers an English as a Second Language (ESL) program that pulls Limited English Proficient (LEP) students (mainly monolingual Spanish speakers and recent immigrants) from their regular classes for English language instruction. The monolingual Spanish speaking children, are referred to as "immersion children," referring to the belief that the more the ESL children are exposed to English, the more English they will learn. Over 80% of Fauna's 800 students receive free or reduced price lunch. Fauna's student population is 30% Limited English Proficiency (LEP), 62% Hispanic, 25% White, 5.2% Native American, 4.3% African American, and 3.5% Asian/Pacific Islander. The school buildings are approximately 40 years old. After World War II, land grants were given to the Hispanic community around the school and some of the families have lived in the area for generations. However, over the last ten years, new immigrants from Mexico have arrived in the area. The school has a considerable transient population, with families moving in and out of the area. Fauna reported a mobility rate of 59% in 1997 and absentee rate of 6.3% in 1998. One block away from the school is an abundance of motels, trailer parks, and pay-by-the-week housing, which contributes to the mobile nature of the student population. Right next door to Fauna Elementary is a state-of-the-art community center run by the city, with amenities that, among other things include basketball courts, a full gymnasium, and computer facilities. The school uses the center for Physical Education activities and some of the students attend after-school programs at the center.

Each classroom has a Macintosh G3 computer acquired in Fall 1998, and/or one or more older Macintosh SE's. Fauna has a math specialist, Mrs. Trimble, who is paid from US Department of Education Title I funds and is in charge of a "Higher Order Thinking Skills" (HOTS) laboratory with 20 Macintosh G3's. Approximately eighty staff members, including administrative, certified, classified, and support staff are at Fauna. Four ESL teachers, four ESL aides, and four reading specialists also form part of the school staff. A year-round calendar at Fauna divides the school year into four sessions each separated by a three-week recess and the school year culminates with a six-week summer recess.

The Classroom

Mrs. Stravinsky's classroom is the only multi-year 2nd-3rd grade classroom in Fauna Elementary. In late April 1999, at the completion of the study, the class had twenty-five students; eleven 2nd graders, and fourteen 3rd graders with thirteen boys and twelve girls. This class was formed by selecting students whose families had lived in the neighborhood for a generation or two and deemed fairly stable. Mrs. Stravinsky started the school year with twenty-one students. Gabriel arrived from Mexico in late November 1998 and Jesus, also from Mexico, arrived in late February 1999. However, over the course of the school year, three or four students left the school and some new students arrived as well. The classroom's ethnicity is one Native American, one African American, one Vietnamese, eight White, and fourteen Hispanic students. Twenty of the twenty-five receive free or reduced price lunch and twelve are classified as ESL students. This excerpt from an interview with Mrs. Stravinsky, November 28, 1998, illustrates the teacher's perception of her students' parents' ability to help them in their learning at home:

> *"For many of them, the parents don't speak English, then they can't help the child in English. They may be able to help in mathematics, it crosses all lines, but they can't help in certain areas. But, very limited. Many of the parents that I've come across are illiterate or they speak another language."*

This statement reflects the expressed belief of Mrs. Stravinsky and also Mrs. Trimble (supported throughout this study) that "Mathematics is a language of its own" and is less impacted by the use of language than other subject areas.

Results of the Study

In the context of Fauna Elementary the following empirical assertions were made as a result of this study:

Assertion 1. The instructional practices of teachers show a broad local definition of technology that coordinates representational tools and presentation systems under the umbrella term, "Teaching Tools."

Assertion 2. For the immersion students, language is critical in providing access to mathematics learning and technology and thus to academic success.

Assertion 1. **The instructional practices of teachers show a broad local definition of technology that coordinates representational tools and presentation systems under the umbrella term, "Teaching Tools."**

For the purposes of this research study, at the outset the researchers defined technology as computer software, Internet, graphing calculators, electronic devices, and other similar devices used as tools in the mathematics education process. However, the researchers took care not to take this definition for granted. Local meanings of technology went beyond this initial definition to include math manipulatives such as pattern blocks, geo-boards, fraction tiles, etc. Use of these manipulatives was

observed consistently during the time spent in the classroom. Mrs. Trimble, the math specialist, vocalized and demonstrated her definition of technology. During an initial interview, when asked how she perceived technology in mathematics education, Mrs. Trimble said:

> *"I see technology as any tool that I use to help get across the concept. Whatever concept, standards, performance objective I'm teaching, technology is the math manipulative, the computer, the overhead; the tools I use to help the students, either in delivery, practice, or assessments. Technology as manipulatives or blocks—pieces of things that they can explore on their desks—helps build the visual concepts."*

Field observations corroborate the local meanings expressed by the teachers. A pattern emerged in the regular use of power blocks, math-fraction tiles, pattern blocks, geo-boards, and paper & pencil. An excerpt from field notes of an observation occasion in Mrs. Stravinsky's classroom illustrates this:

> February 23, 1999.
>
> **Mrs. Trimble:** *What we're going to do today is we are going to do a lesson on relative area and it is going to look like what we have done in geometry already and what we have started in fractions. We are going to use a manipulative called power blocks. And power blocks have like 3 different kinds of triangles, squares, rectangles and parallelograms. They are relatively new. So I'm kind of piloting them.*
>
> The power blocks consist of ten different sized triangles with each triangle numbered T1, T2, and so on. There are five squares, S1 through S5, five rectangles, R1 through R5 and four parallelograms, P1 through P4 in different colors and increasing size. Mrs. Trimble held up different shapes and asked the students to recognize them and say out aloud the name of the shape. Mrs. Trimble gives students five minutes to explore the power blocks and explains to the researcher:
>
> **Mrs. Trimble:** *Now, when they are exploring they are going back to whatever they have mastered like making patterns or sorting by shapes, something that they feel very comfortable with. But because these are pretty new and novel, they are touching them, they are playing with it. I don't think they have gone through exploring this before. They're just going to build after they go through this other thing. They're going to explore whether you give them time or not. They'll turn you off during the lesson and explore, so, if not with their hands, with their eyes, while you are trying to teach. This is the best five minutes spent.*
>
> Mrs. Trimble and the researcher walked around the classroom to discover that some of the students sorted the blocks by shape and size.

Many such instances of classroom use of math manipulatives were observed. The teachers hoped that the use of the manipulatives contributed to mathematics learning experiences that were designed to support the formation and communication

of mental conceptions among learners. The researchers propose that this local definition of technology embodies the notion of cognitive technologies as promoted by Pea (1987). Moreover, it supports the representational perspective on technology (e.g., Kaput, 1995) in that such materially realizable notation systems contribute to the formation of mathematical conceptions.

Use of software programs in the HOTS computer lab was also observed. Students from Mrs. Stravinsky's classroom spent at least two class periods a week in the HOTS lab where software such as the Logical Journey of the Zoombinis™ (Broderbund Software, Inc.) and Turbo Math Facts 3.0 (Nordic Software Inc.) was used. These pieces of software served a distinctly different purpose than the manipulative tools. Whereas the manipulatives were used as ways of revealing students thinking, sharing strategies, and arguing about the structure of mathematics, the computational tools were used mainly as drill and practice scaffolds. Students worked alone on the stand-alone programs, did not interact with each other or the teacher significantly, and did not discuss strategies or underlying mathematical ideas. This contrast is marked, in that while using manipulative tools, the classroom more resembled the kinds of classrooms that emphasize the development of mathematical understanding (Hiebert, Carpenter, Fennema, Fuson, Human, Murray, Olivier, & Wearne, 1997). While using computational tools, however, the classroom more resembled a didactic environment that emphasizes fact production.

These inconsistencies are not uncommon as teachers struggle to implement reformed practices (Koellner & Middleton, 1999). However, the fact that they were so isolated from each other leads us to believe that computational technologies are viewed and implemented utilizing an entirely different set of practices and pedagogical content knowledge than other technologies. The computational technologies were isolated geographically in the HOTS lab instead of integrated into the classroom, the software was designed utilizing a contradictory model of what is important mathematically and pedagogically than the classroom environment and the grouping practices and discursive structures of the classroom and HOTS lab were completely different.

If technologies are available, schools are wired, and exemplary models for implementation are available, it appears that they are not being implemented consistently and in a fashion that is integrated with classroom instruction.

Assertion 2. **For the immersion students, language is critical in providing access to mathematics learning and technology and thus to academic success.**

The very first day, Mrs. Stravinsky mentioned that she has students who hardly know the letters of the alphabet. As the researcher spent more time at the site, a picture emerged that helped the researcher see how language played an important role in the student-teacher interactions and, hence, a significant role in the student's access to learning.

> (Excerpt from Interview with Mrs. Stravinsky, March 11, 1999)
> *We have children in here that are considered immersion children, means that they speak another language and relatively no other language. Although Mariela, when she arrived here was having little command of the language and she's already reading at level 8. In our equivalency, level 8 is the pre primer. I'll just read this level 8 to you.*
>
> > *Baby's birthday. It was baby's birthday.*
> > *She got a book. She played with the paper.*
> > *She got a pair of shoes. She played with the box.*
> > *She got a rocking horse. She played with the ribbons.*
> > *She got a cake. She played with the candle.*
> > *We all sang happy birthday. Then baby went to sleep.*
>
> *Lot of repetition. She got a, she got a, she got, she played with, she played with.*

Varied reading levels of students

The students are at different reading levels. Mrs. Stravinsky has students who cannot identify letters of the alphabet. Mrs. Miller, a reading specialist, works with the Limited English Proficient (LEP) students, some of whom are recent immigrants and monolingual Spanish speakers. Mrs. Miller works with them five days a week for one class period each day. She is the only reading specialist in the entire district who can speak both English and Spanish. Mrs. Miller works with small groups of four or five students for twelve-fifteen minutes each at the reading center. The students are formed into three groups, with one group each at the three centers:

1. listening center—a tape recorder is connected to a device which allows multiple headphones to be plugged in and an audio taped book is played for the students.
2. a reading center which has hands-on visual aids—where students play word games matching visual aids like a toy bear, car, etc, with cards that display a letter of the alphabet and a picture of the visual aid. The students say out aloud B b bear. . .
3. the reading center where Mrs. Miller sits at a U-shaped table with the students facing her and she reads to the students, asking them to follow along with her.

These centers are adjacent to each other at the back of the classroom. While Mrs. Miller works with the LEP children, Mrs. Stravinsky works with the other half of the class on various reading related activities. The following vignette illustrates a typical approach to literacy:

> It is a bright Arizona spring morning, cool and pleasant, in Mrs. Stravinsky's multi-graded 2-3 classroom. Mrs. Stravinsky goes over the day's schedule with her students who are sitting at their desks and is settling herself down at her U-shaped reading table at the front of the classroom. There is an announcement on the PA system "Reading Specialists, Mrs. Elder and Mrs. Glenn are out sick today. Students who work with them should stay in their classrooms and not go to the ESL classroom." Mrs. Stravinsky says, "None of you work with Mrs. Elder. Those of you that work with Mrs. Glenn, stay here." She reaches out to the bookshelf next to her and pulls out a sheaf of papers, copies of a lesson on choosing the right word. She looks at the clock and the bell rings. This is the first class period of the day.
>
> In walks Mrs. Miller from the back door pushing a cart. The cart has a number of white plastic boxes neatly arranged, some are filled with small, thin books, others have plastic bags with toy like visual aids and word cards. She places five of these plastic bags at the round table next to the listening center. She settles down at the U-shaped table at the back of the classroom. Children walk in from the back door, the side door connecting to the adjoining classroom and from the main door. Enrico, Gabriel, Maria, and Mariela from Mrs. Stravinsky's class join the others from other classes and gather around Mrs. Miller.
>
> Mrs. Miller has twelve children around her. Speaking in a low voice so as to not disturb Mrs. Stravinsky, Mrs. Miller, giving instructions in Spanish and English, forms three small groups of four students each. Enrico, Gabriel, Maria, and Mariela, the four monolingual Spanish speakers from Mrs. Stravinsky's room are at her center—the reading table. The others are at the listening center and the reading center.
>
> Mrs. Miller holds up a chart, which has the letters of the alphabet in upper and lower case, and related color pictures. For example: A, a, and a picture of an ant. She holds the chart facing the children and says with a smile: "Let us go over the letters of the alphabet. A a ant." The children point to the drawing of the ant and repeat after her "A a ant." Mrs. Miller goes through the letters of the alphabet B b bear, C c car, D d dog, E e elephant, F f fish and so on. As the students join in chorus, the volume from this table chanting the letters of the alphabet can be heard across the classroom. Enrico put his head down on the table. Mrs. Miller touches his arm gently, directs him in Spanish to sit up and pay attention: "Enrico, escucha." Gabriel, Maria, and Mariela are looking at Mrs. Miller and following along. Enrico yawns. Done with the alphabet chart, she puts the chart back on the wall behind her.
>
> Mrs. Miller reaches up to her cart and carefully pulls out a little book. She leans forward with her elbows on the table and holds up the book "Building with Blocks" with the cover facing the students, points to a red

colored block pictured on the cover page and says, "What color is this?" Mariela says, "Red." Maria stares with a blank look. Enrico is yawning again. Mrs. Miller says, "R-r-red." Mrs. Miller says to the researcher, "Mariela could not speak English when she arrived early this year. Now, she's understanding what she's reading. She can read a lot more than she understands. She knows all her letter sounds, and is just rolling along, everyday. The boys have just arrived from Mexico, it will take a while" and sighs.

Each child at the table has a copy of the book. The book is very colorful and has large pictures of colored children playing with blocks, and the letters are in a large font. Mrs. Miller reads the book twice, asking the students to repeat after her each time, while pointing to the colored block on the page. Again Mrs. Miller provides these instructions in Spanish first and then in English. Mrs. Miller says, "Lean conmigo." "Read with me." She starts the reading; "A green block. A red block. A yellow block. A blue block. A black block. A white block. A spaceship." Enrico and Maria yawn. Enrico puts his head down again. Mrs. Miller tells him in Spanish to pay attention. "Escucha, Enrico." Mrs. Miller looking at the students, trying to keep eye contact with them says, "Open to page 3. Find a word." She holds up three fingers to indicate page 3. Mariela points to Red. Mrs. Miller smiles in acknowledgement and says "r-r-red. Point on A-Z chart." Maria and Gabriel point at "n." Mariela points at "r." Enrico doesn't respond. Mrs. Miller repeats slowly "r-e-d." Enrico seems very tired; he looks as if he has not had enough sleep the previous night. He puts his head down on the table again. This time Mrs. Miller doesn't say anything.

Mrs. Miller collects the "Building with Blocks" books and gives them another book, "At School." Enrico is nudged by Mariela who is sitting next to him and he sits up. Mrs. Miller says, "Diga conmigo. Say with me." Again, Mrs. Miller reads the book twice, with the students reading with her and pointing to the words as they say it out aloud. Mrs. Miller lays the book flat on the table and uses her index finger to trace the words as she reads. Mrs. Miller reads, "I like reading. I like writing. I like singing. I like playing. I like painting. I like my teacher. My teacher likes me." Mrs. Miller pauses and smiles, makes eye contact with the students and says, "Look on page 8. Find 'my,' the letters 'm' 'y'." Mariela and Maria find "my." Gabriel glances shyly around his neighbors and follows. Enrico yawns, looks at Mariela and points at "my." Mrs. Miller collects "At School" from them and gives each student two books to read at home, one that they have already covered in school and the other that is new to them.

Mrs. Stravinsky has the main door open and one of her groups is in the corridor and the other two groups are in the classroom. The group outside is reading chapter 6 of a book with a partner: "It's like This, Cat" by Emily Neville, 1963, Harper Trophy: New York, NY. ISBN: 0-06-440073-5. This book is a winner of the Newberry Medal. Mrs. Stravinsky has Joshua, Jewel, Cathy, and Peter at her reading table. She says, "Look at what you need to do this morning. Everybody, read with your eye while I read out aloud, please. This is part two. Remember, normally this is a test. We are reviewing it. So when you take your test in the spring you are ready. You need to do Questions 5 through 16. Question 5. Choose the word that finishes each sentence

correctly. Fill in the space on the answer sheet with the best answer. Now look at the sample. It says Jason enjoys all outdoor____________. Is it: a.) sport b.) sported c.) sporting d.) sports." Looking at Joshua, Mrs. Stravinsky asks, "What do you think it is?" Joshua replies, "d, sports."

Mrs. Miller's group is singing a song and Mrs. Miller's gentle voice with the children in chorus wafts over to where Mrs. Stravinsky is sitting:

"B b Did you ever see a brown bear, a brown bear, a brown bear, eat blue berries and bugs"

Pointing to the letter A, Mrs. Miller asks, "What letter is this?"

Gabriel says in a low voice, "I." Mariela and Maria say, "A." Enrico just stares at Mrs. Miller. Mrs. Miller smiles and says, "A a The ant ate the apple, A a The ant ate the apple, High-ho the demy-o, The ants ate the apple."

It is evident that the monolingual Spanish speaking students, referred to as immersion students, are at beginning kindergarten reading level in English, while others are able to read chapter books. Fauna has the unique challenge of orchestrating a classroom with students who are native English speakers, students who speak no English at all but speak fluently in their primary language, and a large number of students, mostly recent arrivals, who speak no English at all and have a poor background in their primary language as well. The policy is that instruction is provided exclusively in English. Teachers are unable to provide immersion students the explanation of an important concept in the student's primary language. Krashen, 1996, suggests that first language use in class occasionally is useful rather than teachers resorting to the frustrating use of pantomime and gestures; however, cautions about situations where the input is hard to understand, that concurrent translation is necessary. He espouses the idea of sheltered input.

Language as access to learning

As the observation occasions progressed it was noticed that the immersion children seemed disinterested during instruction, which was primarily in English. Mrs. Stravinsky, the classroom teacher, and Mrs. Trimble, the math specialist did not speak Spanish, even though they made attempts at communicating with their limited knowledge of the language. During mathematics instruction, teachers typically used a math manipulative, allowed students to explore on their own with the manipulative, and gave instructions on how to use them. Instructions are in English, and students with little or no knowledge of English are easily distracted and engage in activities of their own that are not related to learning.

An analysis of the district's learner outcomes for mathematics revealed that 2nd grade students were required to "solve word problems using the appropriate operations." This seemingly simple learner outcome is certainly a challenge to immersion students who are beginning to learn the letters of the English alphabet. The class was asked to solve math word problems as outlined in the "problem of the day" that was done daily. Either the math problem of the day would be announced on the television at the beginning of the day for each grade level or Mrs. Stravinsky would put up a problem on the board. An analysis of the district's Description of Content and Process Clusters Grades 3-5 for the Stanford Achievement Test, showed that one of the goals is for students to be able to compute in context. Under the Mathematics Procedures for Grade 3, "Computation in Context: Solve every day problems requiring addition, subtraction, and multiplication of whole numbers, and addition and subtraction of decimals and money" was listed. Here is an example of the problem of the day that allowed for practicing "Computation in Context."

> (Excerpt from Observation Occasion in Mrs. Stravinsky's classroom, March 1, 1999)
>
> Problem of the day: *My daughter Bridget borrowed $275 from me. She paid me back $127. Now she gave me a check for $411. How much do I keep? How much will she get?*
>
> Most of the non-LEP students were attempting to solve this problem. However, it was clear that the immersion children, who had arrived at Fauna at various times of the school year, were unable to follow the instructions provided in English. Most of the immersion students were engaged in scribbling on the paper, while a few attempted to copy down the numbers that their neighbors were putting down on their sheet of paper.

"Language" began to emerge as the key to access mathematics learning. In the HOTS lab, students sat at a computer each and worked on software that allowed them to practice basic math facts (Turbo Math Facts 3.0). However, the instructions are again verbal (in English) from the software and/or from Mrs. Trimble and the prompts on the screen are in English as well. The immersion students either simply sat at the computer clicking the mouse at random or occasionally, when seated next to another ESL student, ended up talking quietly amongst themselves. In the classroom environment, Mrs. Stravinsky and Mrs. Trimble attempted to communicate with the immersion students in whatever little Spanish they knew and attempted to have other bilingual students translate their instructions from English to Spanish for the benefit of these students. However, during the thirty

hours of observation, fellow bilingual students seldom translated for the monolingual speakers. The immersion students demonstrated behaviors that indicated their loss of interest in the mathematics learning opportunities that were offered:

(Excerpt from Observation Occasion in Mrs. Stravinsky's classroom, February 18, 1999)

Mrs. Trimble: *(to the researcher, explaining the objective for the lesson)*
My objective today is writing fractions. Read, write and speak the fraction, and also to know the different values, which one is smaller and which one is bigger.

Mrs. Trimble: *(to the class)*
I have brought in my fraction bars and we are going to do some fraction bar building. And I'm going to see if you can write a fraction, read a fraction, and build a fraction. So we are actually going to do something that you're not supposed to do until 4th and 5th grade. We're actually going to add mixed fractions, which you are not supposed to know how to do just yet. So don't tell anybody. Okay? (In a conspirator's tone.)

Class: *(Enthusiastically responded.) Yeah!*

Mrs. Trimble gave students five minutes to explore the fraction bars/tiles. The tiles were rectangular in shape, with 1 black tile representing one "whole," 2 orange tiles representing a 1/2 each, 3 green 1/3rds, four purple 1/4ths, five blue 1/5ths, six red 1/6ths, eight brown 1/8ths, ten yellow 1/10ths, and twelve white 1/12ths. We walked around the classroom and were observing what the students were doing during exploration. We saw that Maria had her head down on the desk.

Mrs Trimble: *(to the researcher, referring to Maria)*
You can see that she is not ready

Mrs. Trimble: *(to Maria)*
You are not feeling too well today Maria?

Maria did not respond verbally. She just lifted her head up a little.

Mrs. Trimble: *(to Maria)*
Just need to explore right now . . .

We walked over to Juan. Maria had put her head down again.

Mrs. Trimble: *(to Juan):*
You are ready for the lesson? Huh? What are you doing?
Pauses.

Juan smiled shyly. Juan had the large fraction bar considered to be one whole and on it he was building a pyramid with the other fraction bars. He attempted to cover up his creation with his arms.

Mrs. Trimble: *(to Juan and the researcher)*
Just exploring, seeing how they fit together, very interesting.

Mrs. Trimble: *(to the class):*
Okay. What we're going to do today is, now, we're going to use these (referring to the

fraction tiles) as tools for learning, now that you've used them to explore. I saw some pretty cool exploring going on!

Pauses.

Okay, I want you to hold up the black piece. What does the black piece have on it? What numbers?

Students hold up the black piece in the air. Most students did, Gabriel and Jesus, the two monolingual Spanish speaking children seemed to follow what the other children were doing and catch up by holding up the black piece. Enrico and Mariela are attempting to build some elaborate structure with their fractions bars.

Class: *One.*

Mrs. Trimble: *One. Guess what? This is your "one whole." This is the whole, this is the one. (Holding up the black piece, which is a rectangle shaped plastic piece.)* Pauses.

*Okay, I want you to see if you can make the **ONE** with the oranges (still holding up the black piece, which was designated as "one whole.")*

The students lowered their hands.

Gabriel was yawning. He made eye contact with the researcher and smiled shyly.

Mrs. Trimble: *Lay the black (referring to the tile) on your table and build it with the oranges. Not on top, but right below or right above it.*

Okay. One whole and you are going to build it with the oranges, exactly.

Pauses a few seconds (20 or so). Some of the students like Tony, Joshua, Cathy had their fingers up in the air showing "two" by holding up two fingers.

Mrs. Trimble: *How many oranges did it take? Show me with your number fingers, some of you already did.*

Okay, two.

Who can raise their hand and tell me the fraction that is on the orange tile?

Sara: *One out of two.*

Mrs. Trimble: *One out of two or one half.*

Jane held up one hand and the other hand below it, on the wrist of the first hand with two fingers, indicating one half. Maria had her head down on the table. Juan was busy playing with the tiles.

Mrs. Trimble: *And Jane remembered from yesterday how we said we could do fractions by holding up our one hand with our numerator and holding up the other below for our denominator. She remembered one half.*

Okay. Let me show you what you are not supposed to know until about 4th or 5th grade. Are you ready?

Class: *Yeah.*

Mrs. Trimble: *Today, you're going to write some algorithms. That means math sentences. What does one half plus one half equal?*

Pauses a few seconds.

	Does anyone know? (Walking towards the other end of the room.)
	What do you think it equals?
Connie:	*Two halves.*
Mrs. Trimble:	*Two halves. And what does two halves equal?*
	What do you think it equals (looking at Tony).
Tony:	*One whole.*
Mrs. Trimble:	*Oh! Lets write that.*
	(Writing on the board: 1/2 + 1/2 =)
	An algorithm just means an adding sentence with numbers.
	Pauses.
	Look at this (pointing to what she just wrote on the board.) This is only for 4th and 5th grade.
	Pauses
	One out of two plus one out of two equals. . .
Sarah:	*2/2*
Mrs. Trimble:	*Or. . .*
	Pauses.
Joshua:	*One whole.*

Gabriel was playing with his tiles, looking around at others. Jesus was now opening and shutting the flap of his shirt pocket that had Velcro.

Mrs. Trimble:	*It equals one.*
	(Completes writing on the blackboard 1/2 +1/2 = 2/2 = 1)
	One!
	Okay now I want you to build the black whole. . . Isn't that kinda cool "black whole?" . . .using orange and blue. Just one or two oranges and some purples.

Mrs. Trimble continued with the lesson, leading the students through with the building of the one whole with smaller fractions. She allowed time for the students to build the one whole on their own, providing them an opportunity to test and explore on their own. However, it is necessary to point out that almost none of the immersion students responded to the prompts from Mrs. Trimble attempting to involve them in the lesson. While Mrs. Trimble was leading the lesson, Mrs. Stravinsky walked around the classroom assisting students, or worked with one or two of the immersion students and their bilingual neighbor, if any, attempting to get the point across.

Natural language is used along with mathematical notational systems—both symbolic and visual—during the process of mathematics instruction. Structured experiences provided by the teachers for the students during mathematics instruction used the academic language of English. Instructions on how to use the math manipulatives and the computer software also involved

the exclusive use of the English language. Immersion students did not have any means of understanding the complex "problem of the day," which was presented in written English. The minimal Spanish vocabulary of the classroom teachers proved insufficient in reaching the immersion students as evidenced by the student actions. The reading level of the 2nd-3rd grade immersion students was at a pre-kindergarten or kindergarten level. A few of them were unable to identify letters of the English alphabet. Observation of immersion students' interactions with mathematics technologies indicated that they had little idea of how to operate the technology, let alone learn with the tools. This situates the quality of access immersion students have to mathematics learning and technology. Particularly for the immersion students, sessions involving the use of manipulatives designed to explore math concepts degenerated into playing with them. Sessions involving the computers became random key punching and/or off-task behaviors.

Use of computer software at a level that allows students to explore their understanding of the process of addition and subtraction in multiple representational systems was not in evidence. Multiple mathematical representations that are visual and symbolic allowing students to make the move from simple to more complex and abstract notions are recommended for understanding (Nickerson, 1995, Roschelle, 1996). Most software use instances observed were at the level of practicing facts, using the Turbo Math Facts 3.0 software. This could be attributed to the lack of commercial educational software to enhance mathematical understanding. The use of software programs that purely encourage practice of basic facts suggests that remedial instruction exists in conflict with the use of hands-on math manipulatives that allowed students to explore complex abstract notions in mathematics. In spite of such use of the powerful learning technologies in mathematics education, both the hands-on learning opportunities and the practice software use remained inaccessible to immersion students.

Multiplicity of other factors affecting learning

Social factors play an important role in the school life of students at Fauna Elementary. It was noticed that before school starts and when school lets out, there are very few parents leaving their children or picking them up at school, indicating that mothers and fathers are working. Most children rode the bus. Teachers repeatedly referred to the home conditions of the students as deprived of reading materials and lacking opportunities to engage in reading and/or conversation with English language speakers. Researchers observed students who seemed tired, and wearing unwashed clothes; students going to the nurse's office for shoes or appropriate clothes to attend PE; and students with a cough/cold almost all the time. It is important to acknowledge the complex nature of life and the various issues that contribute to the phenomena.

A report by the district psychologist showed an analysis of Fauna's performance in the Stanford Achievement Test for spring 1997 and spring 1998. The mean percentile rank for grade 3 students at Fauna in spring 1998 indicate that they are at the 29th percentile in reading, 27th percentile in mathematics, and 32nd percentile in language. Mrs. Stravinsky mentioned in an interview that this district psychologist told them that given the number of reduced and free lunches, he could predict the SAT percentile for the grade level.

> (Excerpt from Interview with Mrs. Stravinsky, November 23, 1998)
> *Yeah, I do believe that they (students) are at a disadvantage because of their socio-economic background. There's a lot of violence in many of their lives and then academically if you look at a variety of standards, I know on the Stanford 9 it had shown that our scores in comparison to the free and reduced lunch. I mean, there's a definite correlation between that. And the particular psychologist that spoke to us said that, if we were to give him the percentage of free and reduced lunch he could predict what their Stanford 9's would be. And knowing the other schools in the district, because my two daughters attended a school within this district a different background obviously, but their particular school scored higher in the Stanford 9, but they had a lower percentage of free and reduced lunch.*

This seems like an example of the school district, as an institution, making the correlation that socio-economic background, as determined by the free and reduced lunch status of the students, is related to their academic success, as measured by the Stanford Achievement Test. During one of the observation occasions, as the researcher was checking in with the school secretary, it was noticed that the school secretary was unpacking a huge box which contained several copies of the same book: Payne, Ruby K. (1998) A Framework for Understanding Poverty. RFT Publishing: Baytown, TX. The school secretary shared that the Principal and Assistant Principal had attended a workshop where they came across this book and felt that it was necessary for each one of the teachers at Fauna to read it. As a result, each teacher was given a copy of the book and a study guide. A formal memo from the Principal accompanied the book asking that the teachers read it over the intersession. Thus the school administration was making an attempt to help teachers understand their students' background.

The immersion children seldom have an opportunity, at home with their parents or outside of the school environment, to converse in English and are seldom exposed to print-rich environments. Access to computer programs and software programs outside of school for a majority of Fauna's student population is extremely limited. Teachers perceive that most immersion

students' parents are illiterate. Repeatedly in interviews teachers mentioned that most parents at Fauna were unable to help their children with academics. Parent participation in their children's education as perceived by the classroom teacher is very minimal.

> (Excerpt from Interview with Mrs. Stravinsky, March 11, 1999)
> *Oh! Well. Well, it's interesting because right now, I'm taking two master's classes. There are teachers from districts all over the valley. They speak about how the parents at their schools have these different library drives; they secure books for the libraries. And they even meet them at the bookstore, at Borders! And they'll sit and have coffee with the teacher, and they'll just discuss literature. And then I have to say, "well, that doesn't happen everywhere." And so I have to share with them the reality here is that some of our parents have never been to a library, poor things. And we just had this occur last weekend. Our librarian took a family to the City Public Library. They had never been to the library before. First experience. And the one little girl is in this class and I had one of the sisters' last year and then there's another sister that's in fifth grade. So, both the mother and the father showed up and they don't speak English and the librarian gave them the tour of the City Public Library. And they lost the mom, and they were running around looking for the mom. Well, they found her, she was in the section with the Spanish language books, and she had her nose in a book, she was reading. She was so excited. And obviously the family is literate in a language and I didn't, I really didn't have any idea if they were or not. All five of them have their own library cards now. But, what's interesting too is the fact that the librarian shared the story with me, and not the little girl in this class. And I was surprised because I would think that she would share that. But, then she is so quiet. So, she just didn't share the fact that the whole family went to the library. So, you know, I mean there's an interest. But, true there's such extreme poverty here and illiteracy here that this doesn't always occur. And this is the first time that the librarian's ever done this, that had a family that came to take the field trip.*

This excerpt illustrates that not all immersion students' parents are illiterate. Yet, Fauna's immersion students do not have a better education in their primary language, which is indicative of greater subject matter knowledge; do not have caregivers who are able to help with school work and the time and knowledge to interact with the school; and have access to materials in their primary language and English at home. While the school district psychologist and the teachers seem to subscribe to the view that low SES is causative of low achievement, the researchers subscribe to the view that SES is not causative (Krashen, 1996). In addition to comprehensible input in English, subject matter knowledge in the primary language, and literacy development in the primary language is recommended (Valdés, 1998), however, this is termed Bilingual Education and Fauna's district has adopted an English as a Second Language program, where total immersion is recommended. Fauna has a broad and progressive definition of technology that includes math manipulatives and software programs; yet, the primary focus is on immersing students in English. With this approach the use of mathematics software programs in Spanish though available, are not an option.

In summary, the practices of "immersion" as defined by the district, Fauna school, and the particular behaviors of Mrs. Stravinsky and Mrs. Trimble, were found to be exclusionary in terms of students whose first language is not English. These practices, when coupled with technologies that require the use of English to interpret merely added insult to injury, as the context of one-person-one-machine isolated children from each other and the teachers, who could have provided some basic translation support. In addition, the very tasks the software programs provided students were drill-and-practice oriented, and provided no other support mechanisms for coming to understand arithmetic patterns.

Discussion

Results show two incommensurate sides to technology implementation. One the one side, teachers utilize powerful learning technologies (manipulatives and other modeling tools) as a natural part of their everyday practice. These tools are used to reveal thinking, to offload working memory to free up executive functions, and they are used as tools for communication of underlying, foundational mathematics. On the other side, computational technologies served none of these functions (what Pea, 1987 calls the transcendent functions of technologies). Why?

We suggest four hypothetical reasons for this disconnect. The first deals with **software availability**. The software available to Mrs. Trimble and Mrs. Stravinsky doesn't do the kinds of things that the manipulative tools do. Despite the commercial availability of exemplary packages, Fauna school has yet to purchase any of these packages. Thus, even if the teachers had a perspective on computational media that it should facilitate the transcendent features of technologies, the tools they have at their disposal prevent any of these features to be taken exploited.

The second disconnect exists in the teachers' knowledge of exemplary software. Whereas we have already established that exemplary software were not available, the teachers did not have any experiences (through demos, etc.) of the kinds of computational learning tools that they might want to purchase. Whereas manipulative tools have received the lion's share of coverage (in teacher journals such as *Teaching Children Mathematics*, or in staff development packages), reviews of software, and especially research on its design and use has not been widely available in a format teachers can understand and use.

Third, Fauna school utilizes an impoverished model of technology integration (as it pertains to computers) as an institution. Despite the second author of this paper consulting with Fauna's district technology committee and recommending the infusion of computers and projection systems into classrooms where they can be integrated into instruction (Middleton, Flores, & Knaupp, 1997), the district has opted for continuation of the separate computer laboratory model. This policy preemptively separates computational technologies from the everyday learning experiences of children, and thus exempts children from developing habits of mind that make best use of the kinds of representational and communication tools that computational media afford. To be appropriately integrated into the mathematics curriculum, technological tools need to be available when they are needed (NCTM, 2000).

Fourth, school and district policy constrain teachers' abilities to deal effectively with the issues of language. While the teachers studied believed that mathematics is its own language, separate from a learner's primary tongue, their behavior suggests that mathematics teaching is, regardless of this belief, predicated on effective communication. In Fauna school, effective communication is heavily weighted towards the use of English language instructions for teaching, and verbal English representations of understanding for learning and classroom discourse. Because the computational tools made available to teachers did not facilitate the more robust kinds of communication strategies and representations suggested in the standards documents, Spanish-speaking students were excluded from legitimate mathematical discourse and instead exhibited behaviors reminiscent of learned helplessness such as checking out, daydreaming, or acting out (e.g., Dweck, 1986).

Teachers at the school hold an inclusive definition of technology that exceeds the traditional view that technology is primarily computer-based programs. While the local definitions of technology include manipulatives and other tools that could function to bridge the language gap, seldom were the immersion students able to access these technologies due to their lack of access to the language in which important concepts and classroom management decisions are negotiated. Manipulatives, graphs and charts enable learners to explore and form initial understandings of complex, abstract notions in mathematics; yet, due to the fact that subject matter instruction is in English, the use of the tools by the dominant culture is incomprehensible to students without facility in the dominant language. Results of this study have implications for school policy and practice regarding the role of English in the use of technology for the education of recently arrived non-English speaking children. The most important implication is that the classroom teacher/instructional technologist must take into account the role of language when designing and delivering mathematics instruction and technology to such students by ensuring students understand the academic

instructions that are used in combination with the notational systems, and that the emphasis in discourse be that of *communication* (e.g., NCTM, 1989), instead of *verbal English*. This may suggest the use of "comprehensible input" in sheltered subject matter (mathematics instruction) learning (Krashen, 1996) as a way to facilitate technology integration for all. Providing equitable access to learning, academic success, and fully developing the intellectual potential of all learners is an enormous challenge (Valdés, 1998). The complexity of layering computational technologies into instructional practices compounds these issues.

Clearly, there are a host of other issues that set the context at Fauna: social issues of poverty, race, immigration or citizenship status; policy issues of ESL vs. Bilingual Education; funding issues with regard to the hire of bilingual educators, district policy and teacher/administrator perceptions of Limited English Proficient/immersion students and so on. Recognition of the complexity of Fauna's context, as a reasonable case of technology implementation, helps shed light on the historical difficulty schools have had providing equitable access to their second-language learners.

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