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RESEARCH ARTICLE

Improving technology literacy: does it open doors to traditional content?

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Abstract This study investigated whether an identifiable link existed between gains in technology literacy and achievement in the areas of reading, mathematics, and language arts. Normal curve equivalent (NCE) content score changes from TerraNova assessments were calculated for approximately 5,000 students from fourth- to fifth-grade and 5,000 students from seventh- to eighth-grade. These changes were compared to relative gains from a pre- to post-assessment in technology literacy. The rationale that a correlation might be expected is grounded in two ideas: (1) technology literacy gains lead to heightened subject specific confidence, and (2) technology literacy gains reflect improved ability to use technology as a mediator of new learning. If correct, both of these conjectures would predict increased academic achievement among students experiencing gains in technology literacy. Results provided evidence of such connections between technology literacy gains and language arts skills.

Keywords Technology literacy · Achievement · Student achievement · Language arts

When the term "knowledge worker" was introduced nearly half a century ago (Drucker 1959) the characterization was largely limited to those who worked for a living doing tasks of planning, analyzing, programming, and generally transforming information. Since that time, in the United States, being educated or literate in the use of technology has become widespread but not necessarily universal. Prensky (2006) claims that today's students are digital natives who are "fluent in the digital language of computers, video games, and the Internet" (Prensky 2006, p. 9). It is agreed that most students today have spent their lives surrounded by technologies such as computers, videogames, and cell phones. Yet, the digital native metaphor assumes digital literacy. While students today are certainly far more comfortable and confident in approaching technological tools than students of

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20 years past, this poise does not necessarily translate into being literate in technology. Students are typically comfortable using end products of the technology world such as the Internet and video games, and the case can certainly be made that the Internet and video games possess potential to foster critical thinking. More often, though, commonly used technology interfaces impel students to be product consumers and not engineers. That is, students may be motivated to persist in playing videogames to *level up,* can be handy with text messaging on cell phones, or are adept at scanning scores of web pages to extract information needed for a report, but it's not necessarily clear to assume that these activities promote students to become more technologically literate in broader or deeper ways.

The *National Educational Technology Standards (NETS-S) and Performance Indicators for Students* (ISTE 2007) represents the emphasis placed nationally on promoting technology literacy. Notably, beyond just operating technological tools, at the root of technology literacy, are the abilities to use those tools to solve unique problems, analyze information, and model complex ideas. Determining students' level of technology literacy is not a matter of cataloging computer time; it is about engaging students in experiences such as manipulating databases to yield meaningful information or employing technology to help weigh decision factors.

Simply stated, tool use does not presuppose literacy. There exists a stratum of technological literacy possessed by both digital natives and digital immigrants. The term *fluency* can be used here to represent the depth and breadth of technological aptitudes and abilities in a variety of areas such as databases, telecommunications, and multimedia presentations. Just as an inclusive definition of language literacy encompasses oral expression, verbal communication, reading comprehension, and writing ability, technology literacy must also be defined widely to illustrate true proficiency. An individual with low technology literacy abilities can be imagined as a true novice or as an avoider of technology; a highly fluent individual is expert in several areas of technology and able to assist others. Movement within the technology literacy range may occur in both directions (i.e., become more or less fluent).

The design of this study did not delve into the question of whether or not the existence or the use of technology in schools leads to academic gains. Several studies have addressed this question and have examined the correlation between technology use and its existence with student achievement and attitudes (e.g., Schacter 1995; Wenglinsky 1998; Wenglinsky 2006). Rather, this study was designed to concentrate on the *when it happens* aspect of technology literacy. Studies, to date, have not investigated technology literacy itself as a variable that affects student achievement. A typical educational technology research design examines whether the "XYZ Ed Tech Program" (input) affects student achievement (output). Missing between these beginning and end points is an examination of students' technology literacy. Specifically, the question asked was when students improve their technology literacy, are there positive effects in traditional subject areas? Conversely, when students improve their technology literacy, has this been achieved at the cost of losing ground in those traditional subject areas?

Researchers have described students whose technology competence leads to successful academic achievement as "open door" students (Cuban et al. 2001; Peck et al. 2002). These researchers described open door students as having gained a sense of self-confidence and a drive to do well in school and that this stems from their increased technology proficiency. Open door students assess their own technology abilities to be greater than other students and see their expertise in technology as a means to change in other areas. The open door students are described to be those "whose lives changed with increased access to technology" (p. 823). Yet Cuban et al. typify the open door students as a subset within a larger group of students, all with equivalent access to technology at school. Similarly, Cuban et al. do not provide information to distinguish whether the open door students actually have greater access to technology at home or if they simply make greater use of available technology tools. On these grounds, it is proposed that it is not increased *access* to technology but increased *ability* with technology that can serve as a catalyst for improvement in academic subjects. More specifically, it is conjectured that it is the increasing or enhancement of technology literacy that promotes growth.

Theoretical basis

The conceptual foundation supporting the idea that improvement of technology literacy can be connected to gains in other content areas is grounded in two non-opposing theories: (1) improved technology literacy leads to heightened self-confidence and in turn fosters improved academic achievement (confidence theory), and (2) improved technology literacy represents increased ability to use technology tools as mediators of knowledge (mediation theory).

Regarding the first idea that improved confidence that is based on advancing technology literacy can lead to broader content gains, there exists supporting research related to the ideas of self-efficacy, self-concept, and motivation. Several studies have indicated that confidence and motivation can play a role in promoting achievement (Bandura 1997; Anderman et al. 1999; Wilson and Trainin 2007). In some cases, students may view technology as an efficient means of facilitating their learning; these students may then evaluate their use of technology as an attribution—a cause for academic success (Weiner 1985; Wilson and Trainin 2007). Depending on how technology is used, the perception of it as an attribution to academic achievement may be influenced. For example, if the goal is simply to submit a short essay free of misspellings, then a simple spell check program can support this objective. Of course, it is doubtful that thoughtful students would consider themselves to then be better spellers. However, if the use of technology consistently contributes to higher quality essays because the technology allows the students to easily rearrange sentences, organize ideas, and revise assignments based on teacher feedback, then it is conceivable that students would attribute in part their own mastery of writing to technology.

Meshing the ideas of open door students and attribution theory, if technology use promotes student achievement, then technology would be viewed by open door students as being within their control. Conversely, low achieving students more typically attribute outcomes to things such as luck and lack of assistance, reasons outside of their control (Wilson and Trainin 2007). A measurement of actual control over technology is technology literacy. While this differs from perceived control, it provides a gauge of student ability to employ technology to support many classroom objectives. It is then conjectured that students who experience quickened progress in their technology literacy skills are likely to view technology as an attribution to academic success and feel more confident in their own ability to master learning objectives. For these open door students, who have gained confidence in content areas, attributed at least partly to gains in technology literacy, the catalyst is much as Leamnson (2001) described when discussing conditions where technology can enhance learning:

> Something (or somebody) has stirred up an interest in the student and the technology is available to satisfy and exploit that interest. The interest intended here is not in the

> technology itself, but in some content, or problem, or body of information that is made available by the technology. (p. 78)

The second theory posited here is that of mediation and it is grounded in the work of Vygotsky. Traditionally, a Vygotskian outlook on learning is that knowledge becomes refined and gains coherence through mediation. Mediation itself is the way in which external events are transformed into internal mental functioning (Vygotsky 1978). Mediation is then considered the instrument of cognitive change (Kozulin 1990). The source of mediation can be a system of symbols (e.g., language), human behavior, or a material tool. Computers as sources of mediation have been placed under the category of material tools along with pieces of string tied around one's finger as reminders (Huong 2003). However, this classification of computers may be a gross misrepresentation of their potential.

When used dynamically, computers become a unique means of mediation. Technology tools can manipulate information and data, facilitate communication, and promote presentation. Technology permits all of this with great allowance for refinement through iterative revisions. Revisions then demonstrate, if not genuine reflection, at least minor modification of thought. Within this perspective, computers, as sources of mediation, are far more complex than plain icons or simple learning aids. The computer can become an interface that allows a learner to mediate understanding of new knowledge. Essentially, according to Vygotsky, higher mental processes are mediated by psychological tools such as language, signs, and symbols (Karpov and Haywood 1998). A computer can then be viewed as either a tool itself or a different medium that includes several sources of mediation (e.g., print, video, mathematical representations). In either case, when the relationship between a user and a computer is at a level of mindful engagement, the result can be skill stretching and intellectual internalization of new learning (Salomon 1990). Salomon et al. (1991) describe this as a partnership with technology whereby skills and strategies that can be transferred to other situations are developed. Ideally, the result is an intellectual partnership between the technology and the user that allows the individual to clarify new ideas.

Solving subject-domain problems requires the acquisition of cognitive mediation tools (Karpov and Haywood 1998) and technology may at times be such a tool. An upsurge in a student's ability to skillfully and broadly use technology as a source of mediation would manifest in improved technology literacy. If a student has then discovered a new or enhanced way to mediate learning, it is expected that achievement in the traditional content areas will also improve. Even in the absence of the mediation tool (i.e., the computer) it is expected that the student would still demonstrate new comprehension achieved through any such shared cognition.

Cuban et al. (2001) reported that they did not observe doors opening for all students and it is not proposed that technology is a powerful mediation tool for all users. Instead, technology literacy, much like language literacy, likely acts as a gatekeeper. As technology literacy improves, the ability to use technology as a mediation tool also develops. In turn, learning is better facilitated. The variance in technology literacy among students is the true type of digital divide Warschauer (2006) refers to:

> … not that some people will have computers and some won't, but that they will be enabled to use them in entirely different ways, with one group able to muster a wide range of semiotic tools and resources to persuade, argue, analyse, critique and

interpret, and another group, lacking these semiotics skills, limited to pre-packaged choices. (p. 164)

Two theories have been provided (confidence theory and mediation theory) to support an expectation that increased technology literacy leads to improved academic achievement. It is proposed that the mastery of technology literacy may promote self-confidence and/or facilitate learning as a mediation tool. The emphasis here is on making gains in technology literacy and not on the mere use of technology. If technology literacy is on a positive trajectory, there is basis to hypothesize that academic achievement rates will have parallel slopes. Whether the trigger is self-confidence or acquisition of mediation ability, the effect would be manifest in improved academic achievement.

Background

During the 2006–2007 academic year, more than 15,000 fifth- and eighth-grade students in Arizona were assessed at the beginning of the fall semester and again near the end of the spring semester to determine their technology literacy. The assessment administration was carried out by Learning.com and overseen by the Arizona Department of Education (ADE). All of the assessed students were enrolled in districts that had received monies from the federal Title II-D Enhancing Education through Technology funds allocated to Arizona. Some of the districts were awarded these funds through a competitive grant process while other districts received funding through formula-based allocation. In both cases, the districts were to demonstrate a high need based on at least 29% of students being in poverty and had to serve one or more schools that were low performing on Adequate Yearly Performance (AYP) academic measures.

Schools within each of the districts receiving monies were identified by district administrators to receive the funds for targeted educational technology programs. The projects that resulted from these funds were generally diverse with the common elements among them being that they all provided teachers with professional development, were located at specific schools, and integrated educational technology with the goal of supporting proficiency in traditional content areas.

An initial evaluation of pre- to post-assessment results considered the differences between students in formula-granted schools and students in schools that received money through a competitive process. A reason for the comparison was to determine the value of additional manpower costs expended by the state department and schools when facilitating a competitive sub-award process. With analyses at the district, and school levels, this earlier study revealed no significant differences. Students in fifth- and eighth-grade, in both the formula-based and competitive-based grant schools, made marginal overall technology literacy gains from pre- to post-assessment, but there were no educationally or statistically significant differences between the groups based on this classification.

A research question about technology literacy itself then emerged. Data analyses had shown that in both grades and across all of the examined schools there was a wide range of technology literacy gains made among students—with some students even experiencing negative change from pre- to post-assessment dates. The interest was to detect if doors truly were being opened for those students demonstrating greatest gains in technology literacy. Were technology literacy gains paralleled by gains in other content areas?

Methods

Instruments

Technology literacy was measured with the TechLiteracy Assessments™ developed by the company Learning.com. The elementary and middle school versions of the TechLiteracy Assessments™ (TLA-EL and TLA-MS, respectively) were administered to fifth- and eighth-grade students. The assessments were developed to authentically assess elementary and middle school students within the construct of technology literacy as laid out in national content standards. The assessments address the National Educational Technology Standards for Students (NET-S) published by the International Society for Technology Education (ISTE) (TechLiteracy Assessment frequently asked questions 2006). The assessments are a mix of knowledge-based questions and interactive performance based items. The TLA-EL and TLA-MS assessments do not survey students about disposition toward technology; rather, the assessments measure student technology proficiency. To illustrate, an item from the TLA-EL sample test presents students with a typical word processing screen and asks them to click on the SAVE icon. A sample item from the TLA-MS provides students with multiple website links that include the word "baboon" in the title (as might result from a typical keyword search) and asks students to indicate the most useful link for writing a report on desert baboons.

Validity of the assessments and proficiency cut points were established through field testing of 8,000 students across 68 schools in seven districts in 2005 (Patelis et al. 2006a, b; Sireci et al. 2006). The TLA-EL and TLA-MS assessments are comprised of subcategories in the areas of (1) system fundamentals, (2) social and ethical issues, (3) word processing, (4) spreadsheets, (5) multimedia presentation, (6) telecommunication, and (7) databases. Examples of the key objectives within each subcategory are provided in the Appendix. The assessments were completed online and students responded to a mix of knowledge based questions and interactive, performance-based items.

Proficiency in content areas of mathematics, reading, and language arts was measured with the TerraNova assessment. The TerraNova is a standardized norm-referenced achievement test developed by CTB/McGraw Hill that compares students' scores to scores from a norm group. The norm group for TerraNova is a national sample of students representing all gender, racial, economic, and geographic groups. Arizona administers TerraNova assessments in the spring of each school year. The reading portion of the TerraNova assesses comprehension of non-fiction, fiction, and functional text (e.g., advertisements). The mathematics portion of the TerraNova assesses students' abilities to compute and apply appropriate concepts to problem-solving situations. The language arts portion of the TerraNova assesses punctuation, grammar, language expression, the ability to manipulate words, phrases and clauses and the ability to recognize correct sentence structure and writing style. Normal curve equivalent (NCE) scores from the TerraNova assessment were examined to study achievement in the traditional content areas of mathematics, reading, and language arts. NCE scores are represented on a scale of 1–99. This scale coincides with a percentile rank scale at 1, 50, and 99. Unlike percentile rank scores, the interval between scores is equal.

Sample

Regarding the TechLiteracy Assessments™, fifth- and eighth-grade students completed their respective exams as a pre-assessment early in the fall semester of 2006 and completed post-assessments late in the spring semester of 2007. Data were filtered to include only those students completing both a pre- and a post- TLA-EL or TLA-MS.

Unique student identification numbers were used to match the TerraNova scores of students from when they were in either fourth- or seventh-grade in 2006 to corresponding fifth- or eighth-grade TerraNova achievement in 2007. This vetting of the data led to an approximate 25% reduction. NCE differences were calculated to determine changes from fourth- to fifth-grade and from seventh- to eighth-grade. The NCEs of all other students in Arizona, who completed the TerraNova in these same grades, were additionally examined for comparison.

Analysis

TLA-EL and TLA-MS raw score results were converted to scale scores with possible scores ranging from 100 to 300 and proficiency set at 220 by Learning.com. A Pearson correlation analysis was conducted to determine the overall relationships between the changes in technology literacy, as measured by the TLA-EL and TLA-MS, and changes in traditional content areas, as measured by NCE scores on the TerraNova. These results are presented in Table 1.

The results in Table 1 do indicate significant positive correlations between technology literacy gains and traditional content gains in most categories. However, given the large sample sizes that often yield statistically significant correlations and the small r values, these results were considered interesting but far from convincing.

Because researchers (Cuban et al. 2001; Peck et al. 2002) had previously observed the door opening phenomena occurring only among a few students, there was the implication of a unique effect occurring with a few students. Attempting to discover those few was a key to this study. Consequently, this examination pared out the cluster of greatest technology literacy gainers by grouping the students based on grade level and quartile rankings. The top quartiles for the fifth- and eighth-grade groups were comprised of those students who had made the greatest scale score gains in technology literacy and were labeled the high gain groups. The second and third quartiles were labeled the medium gain groups. The lowest quartiles for the fifth- and eighty-grade groups were those students who made the least gains in technology and were labeled the low gain groups (Table 2).

One-way ANOVA and Tukey post hoc tests were used to determine differences on the TerraNova assessments among the low, medium, and high TechLiteracy groups. Differences were considered significant at $p < .05$. When significant differences were found among the groups, effect sizes were calculated to measure the strength of the relationship between the high TechLiteracy group and the other two groups. It was not possible to

Table 1 Correlations between traditional subject gains and technology literacy gains

	4th to 5th grade			7th to 8th grade		
	r	*p*	*n*	*r*	*p*	*n*
Math	.043	.001**	5955	.041	.004**	5086
Reading	.030	.020*	5958	.008	.571	5089
Lang. Arts	.076	.000**	5958	.062	.000**	5089

* Correlation is significant at the .05 level (2-tailed)

** Correlation is significant at the .01 level (2-tailed)

Table 2 Technology literacy achievement of low, medium, high gain groups

Grade	TechLiteracy gain group	n	Pre-assessment		Post-assessment		Mean scale score change
			Mean scale score	SD	Mean scale score	SD	
5	Low gain	2044	181.9	37.0	166.5	37.9	−15.4
	Medium gain	4047	188.8	38.9	203.7	39.4	14.9
	High gain	2063	175.2	30.1	221.4	29.6	46.2
8	Low gain	1742	195.0	42.0	182.1	45.0	−12.9
	Medium gain	3386	200.7	39.0	219.8	38.9	19.1
	High gain	1689	175.9	28.2	226.8	26.6	50.9

aggregate data at the classroom level because classroom identifiers were not available. To obtain adequate statistical power for this exploratory study, student data were aggregated across schools and districts to determine members of the technology gain groups. Guided by the open door observations made by other researchers, this exploratory study focused on the *when it happens* aspect of technology literacy. Discovering students who had experienced relatively high technology literacy gains and determining the relationship to gains in traditional content areas was the research focus.

Results

Grouping the fifth- and eighth-grade students based on TechLiteracy gains led to an interesting finding. For both grades, the high TechLiteracy gain groups had the lowest mean pre-assessment scores. This may not be entirely surprising, as the groups with the lowest pre-assessment scores consequentially have the greatest potential for growth and a ceiling effect in research is not uncommon. However, in both grades, the high TechLiteracy gain groups also obtained the highest mean post-assessment scores. The groupings were based on scale score gains so it is not inferred that all members of the high TechLiteracy gain groups began with low TechLiteracy scores, or even that all members of the high gain groups ended with relatively high TechLiteracy scores. Rather, it is pointed out, that on average, the groups with greatest TechLiteracy gains began with the lowest mean and ended with the highest mean. Though the underlying reasons are yet unclear, it does appear that these groups closed any technology literacy gap. Learning that groups that began (pre-assessment) with the lowest mean scores then attained (post-assessment) the highest mean scores might be gratifying. However, given that these data are at the student level and that earlier analysis revealed no significant school or district effects, it is interesting that the groups with highest pre-assessment means did not maintain their edge. Provided in Table 2 are the pre- and post-TechLiteracy mean scale scores and mean changes for the three TechLiteracy gain groups in fifth- and eighth-grade.

Ethnicity and gender of students within each gain group was examined to distinguish discernible patterns. Though no defined relationship was observed that was related to ethnicity and gain groups, it is notable that the fifth- and eighth-grade high TechLiteracy gain groups were both comprised of 53% females and 47% males.

Descriptive data for the three TechLiteracy gain groups and all other Arizona students are provided in Table 3 and represented graphically in Figs. 1 and 2. These data represent the NCE mean scores on the TerraNova content assessments in 2006 and 2007.

Table 3 Mean NCE scores, 2006 and 2007, by TechLiteracy gain groups

	2006						2007					
	Math		Reading		Lang. Arts		Math		Reading		Lang. Arts	
	n	NCE	*n*	NCE	*n*	NCE	*n*	NCE	*n*	NCE	*n*	NCE
4th to 5th grade												
Low gain	1535	44.4	1538	40.3	1538	41.3	1536	40.6	1535	41.9	1535	41.0
Medium gain	2962	52.1	2964	48.6	2964	49.4	2964	49.3	2965	51.0	2965	50.7
High gain	1458	53.7	1459	49.5	1459	49.9	1461	51.2	1461	52.4	1461	52.5
Others in AZ	68363	53.7	68404	50.5	68404	50.9	68453	50.6	68467	52.5	68467	51.8
7th to 8th grade												
Low gain	1285	45.0	1285	44.2	1285	47.0	1288	46.9	1288	46.3	1288	45.4
Medium gain	2523	50.2	2523	50.4	2523	52.7	2527	52.8	2527	52.4	2527	52.2
High gain	1278	46.9	1281	46.3	1281	48.4	1282	49.7	1283	48.9	1283	48.9
Others in AZ	67109	51.4	67143	51.9	67143	53.8	67120	53.8	67149	53.3	67149	52.7

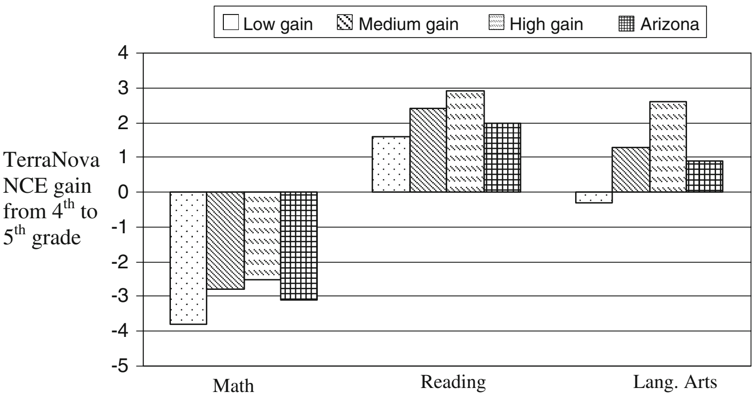

Fig. 1 TerraNova NCE gains, 4th to 5th grade, grouped by low, medium, and high technology literacy gains. Other Arizona students included

ANOVA tests revealed that there was a significant difference ($p < .05$) among the TechLiteracy gain groups in the content area of language arts for both the fifth-grade [$F(2, 5951) = 13.01$, $p < .001$] and eighth-grade students [$F(2, 5074) = 6.78$, $p = .001$]. Results indicated non-significant differences among the fifth-grade groups in the areas of mathematics [$F(2, 5945) = 2.79$, $p = .06$] and reading [$F(2, 5951) = 2.68$, $p = .07$]. Likewise, the differences among eighth-grade groups was non-significant in mathematics [$F(2, 5074) = 1.30$, $p = .27$] and reading [$F(2, 5074) = 0.61$, $p = .54$].

Figures 1 and 2 also indicate that in all cases except for seventh to eighth grade reading, that there was a step-like progression from the low TechLiteracy gain group to the high TechLiteracy gain group. Even in the case of seventh to eighth grade reading, the high TechLiteracy gain group had larger NCE gains than the low or medium TechLiteracy gain group. Post hoc analyses of the fourth- to fifth-grade students, using Tukey post hoc criterion for significance, indicated that the gains in NCE language arts scores were significantly greater for the high TechLiteracy gain group ($M = 2.61$, $SD = 15.12$) than those

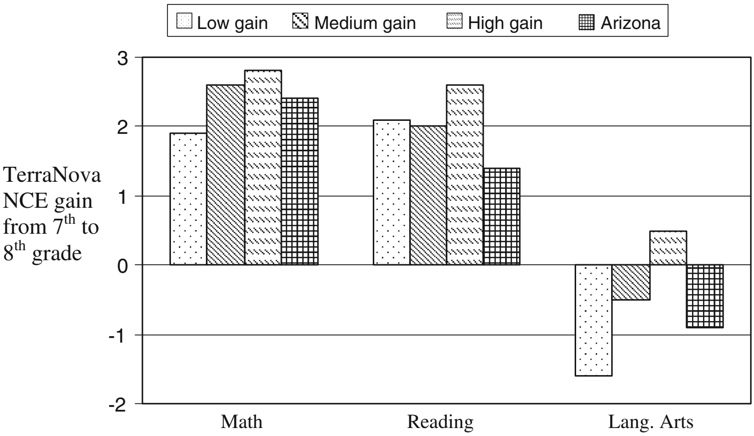

Fig. 2 TerraNova NCE gains, 7th to 8th grade, grouped by low, medium, and high technology literacy gains. Other Arizona students included

of the other two gain groups. A similar result was observed in the seventh- to eighth-grade group; NCE gains were significantly greater in language arts for the high TechLiteracy gain group than for the other two gain groups (M = 0.50, SD = 14.55). Because the ANOVA results indicated significant differences in language arts, but not in mathematics or reading, effect sizes were calculated to determine the magnitude of this language arts relationship between the high TechLiteracy gain groups and the two other groups in each grade. In both fifth-grade ($d = 0.1$) and eighth-grade ($d = 0.1$) the Cohen's effect sizes were small and interpreted to represent minimal relationships.

Discussion

The confidence and mediation hypotheses were proposed to suggest that improved technology literacy could be an important means toward increasing general academic achievement. The design of this study was not to pit these two hypotheses against each other and ferret out the relative value of one over the other. Instead, the hypotheses were developed following post hoc observations of collected datasets and a review of related literature. Therefore, unlike a classic research sequence—observation of phenomena, hypothesis development, experimental design, and data collection—these circumstances first provided data from which phenomena was observed. The intention was to determine what happens to academic achievement when students demonstrate pronounced technology literacy gains. The confidence hypothesis and the mediation hypothesis both presented plausible rationale as to why academic gains might be anticipated among students improving their technology literacy.

The results provide some support for the supposition that improved technology literacy and academic achievement are correlated in the area of language arts. It is important to note although the gains in language arts were greatest for the high TechLiteracy gain groups, that these language arts gains are seemingly small. This is particularly true among the eighth-grade high TechLiteracy gain group which experienced only a 0.5 NCE gain in language arts from 2006 as seventh-graders to 2007 as eighth-graders. However, it is also noted that during this same time period, that the eighth-grade low- and medium-

TechLiteracy gain groups experienced a decrease in their language arts NCE scores. Additionally, the effect sizes that compared the gains in language arts made by the different TechLiteracy gain groups were small in both grades. The results provide marginal support for the connection between technology literacy and language arts. Yet it is believed that there exists enough evidence here to warrant further consideration of the language arts connection.

Although computers and related technology can be used to support all school subjects, students today use computers in schools more for word processing than any other function (Becker 2000). While technology in schools can take on many forms such as probes, digital editing equipment, and MP3 players, it is still the computer and the venerable keyboard that is the chief technological presence in schools. The keyboard interface naturally provides a simple method to word process or *process words* and it is easy to imagine that students who often use word processing programs might be improving related technology literacy skills. Yet, if it were just a matter of students interacting with word processing software as a means to improve technology literacy, we would expect broad and uniform gains. This did not happen. In fact, the low-gain groups experienced decline in technology literacy and this was paralleled by their retreating NCE scores in language arts. What may be in play is what Salomon et al. (1991) indicated are ways in which individuals can interact with technology; perhaps some students have developed better partnerships with the technology and their technology literacy and language arts skills improve in synch. Why those students, who made greatest gains in technology literacy and significant gains in language arts, did not also make significant gains in mathematics and reading may simply be due to there being less opportunity to mediate mathematics and reading through technology. That is, if gains are made in technology literacy, then gains in traditional content areas would only be expected if students are provided ample opportunity to apply their new technology literacy ability to the content. It is supposed that this occurred for some students with language arts, but due to lack of exposure through technology to mathematics and reading, the same gains were not observed in those content areas.

The implication of this study is unfortunately not a simple one. The Title II-D programs did not yield broad based gains in technology literacy. However, for the students who did experience those gains, improvements were also observed in language arts. Returning to the confidence and mediation theories that were presented as possible frameworks, the evidence is such that either one or both of these suppositions explains the observed relationship. If one or both of these theories is at play for open door students, then technology literacy gains perhaps may be viewed as inroads to gaining confidence or building new mediation skills. The reality that word processing is the most common use of technology in schools, may just mean that language arts has a built-in advantage over mathematics and reading. If, for example, students instead more prominently used computers in schools for mathematical functions such as manipulating data, modeling equations, creating charts and graphs, then possibly these data would have shown similar gains in mathematics for the high technology literacy gain groups.

Subsequent to the research question of what happens when students make gains in technology literacy, is the question of why do some students experience these gains and others do not? These data may provide some direction for future study. An initial focus might be to consider the fact that the high technology literacy gain groups initially had the lowest TechLiteracy mean scores but achieved the highest TechLiteracy mean scores on the post-assessments. This "coming from behind effect" may not be just interesting, but may play a role in how students perceive their own use of technology. If the confidence hypothesis is valid, then it may be that students with initially lower technology literacy skills possess greater likelihood to develop a desire to further these skills. Upon witnessing their own improvements, dynamics may then follow the ideas of the attribution theory as students attribute their greater language arts skills to their improved technology literacy.

If the mediation hypothesis also has merit, then the high gain students have experienced a leap in their ability to mediate understanding with technology. Determining the legitimacy of this hypothesis will require structured interviews and analyses of students' thought processes. If language arts skill building is occurring more prevalently among students who are making technology literacy gains, the expectation is that thinking or learning about language is being shaped by the context of technology. For these students, the role of the computer is moving away from being a supplier of a curriculum or even from being a blank slate, but in the meditational role the student is engaging the technology as a better tool to reconcile understanding.

Through observation and interviews, Cuban et al. (2001) perceived that sometimes technology could facilitate entry to academic achievement. The researchers termed these pupils as the open door students. The design of this research has taken a closer look at this premise. By first resolving which students made gains in technology literacy, the result was to essentially determine which students held a key (or a better key) to those doors. The outcome provides some evidence that students were able to more easily open the language arts door when they held such a key. The challenge for researchers and educators is to facilitate strong technology literacy gains more universally and to help students possess the keys to other content areas.

Appendix

Subcategory	TLA-EL examples	TLA-MS examples
Systems and Fundamentals: assesses tasks central to the understanding and use of computer systems	Knowledge of the parts of the computer Storing and retrieving files on computers or networks Basic technology vocabulary	Creating, storing and retrieving data on local area networks and peripheral devices Basic troubleshooting for computer problems Recognizing and distinguishing among file types
Social and Ethical: assesses knowledge about accepted ethical norms as they relate to technology, as well as the impact of technology, past and present, on society	Identifying ethical and unethical uses of technology tools Awareness of the social and ethical concepts associated with network and telecommunications use Understanding the basics of online safety	Identifying ethical and unethical behaviors with respect to the use and transmission of electronic files, software and other online data Awareness of major social issues and ongoing effects and controversies regarding prominent technology advances
Word Processing: assesses tasks central to formatting text and text/page layout	Publishing and saving documents such as letters and short papers Formatting text	Publishing, printing and saving documents in a variety of locations Applying standard text formatting and layout options Applying layout options at the paragraph, page and document level

Appendix continued

Subcategory	TLA-EL examples	TLA-MS examples
Spreadsheets: assesses tasks central to creating, editing, manipulating, and interpreting data in spreadsheets, charts, and graphs	Creating worksheets Entering and saving information Creating and interpreting basic graphs Formatting cells	Creating, entering, sorting, filtering and saving information Writing simple formulas Creating, labeling and interpreting more complex graphs
Multimedia and Presentations: assesses tasks central to the creation and manipulation of graphic, audio, and video by electronic means	Creating and editing multimedia projects Communicating effectively to a variety of audiences using multimedia Using video recorders to capture images and edit clips for use in video or other multimedia	Inserting graphics and other multimedia into documents Creating, formatting and saving presentations Capturing and composing audio-visual presentations
Telecommunications and Internet: assesses tasks central to telecommunications and internet software	Recognizing and comparing basic methods of online communication Navigating from one web site to another Accessing and sending e-mail	Navigating from one web site to another Assessing content purpose and credibility as grade appropriate
Database: assesses tasks central to the use of common database interfaces, such as Web search engines and library records	Using web library search engines Searching using single and multiple keyword searches	Searching the web or other databases using both single and multiple keyword searches Sort, filter and search simple databases

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