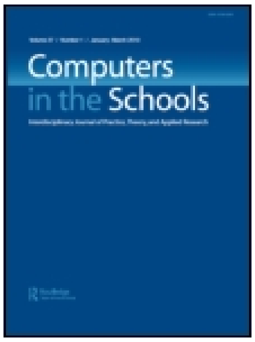


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# Examining Student Digital Artifacts During a Year-Long Technology Integration Initiative

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*This study was situated within a year-long, statewide technology integration initiative designed to support technology integration within science, technology, engineering, and math classrooms. It examined the elements used in student artifacts in an attempt to investigate trends in digital artifact creation. Among several conclusions, this examination highlighted areas of significant improvement in student use of technology, such as an increase in the creation of PowerPoint presentations and the inclusion of multimedia elements. The study also highlighted areas for improvement, such as the low cognitive demand for content in the majority of the artifacts.*

*KEYWORDS* *educational technology integration, technology, student artifacts, 21st-century skills, K–12, technology literacy*

Educational policies have made technology literacy an educational priority, as technology might enhance learning, productivity, and performance (Davies, 2011; Evans, 2005), which is linked to global success (Evans, 2005; International Society for Technology in Education [ISTE], 2007; U.S. Department of Education [USDOE], 2010). The impetus for technology integration in the classroom has played out in the 2001 "Enhancing Education through Technology" (EETT) initiative (USDOE, 2010). The aim of this initiative was

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to improve student achievement in elementary and secondary grades through the use of technology.

This study was situated within a statewide EETT initiative designed to improve technology use in science, technology, engineering, and math (STEM) classrooms. STEM classrooms were targeted because of the tremendous need for more students to pursue STEM-oriented careers (Langdon, McKittrick, Beede, Khan, & Doms, 2011). Such careers command higher salaries, support economic and global strength, and are predicted to grow at significantly greater rates than non-STEM careers over the next decade (Landgon et. al., 2011). In addition, STEM studies facilitate development of important skills for all students such as problem solving and deductive reasoning (Carnevale, Smith, & Melton, 2011).

Science and mathematics are emphasized over technology and engineering in most K–12 schools in the United States. This is due, in part, to national and international assessments showing that American students underperform in these areas compared to peers in other countries (Fleischman, Hopstock, Pelczar, & Shelley, 2010; National Center for Education Statistics, 2009). This initiative was no exception, and all participating teachers were assigned to math or science classrooms despite the STEM language used in the program description. This study examined the digital artifacts created by students within these math and science classrooms.

## PURPOSE

Research suggests that increasing teachers' opportunities to engage with technology can lead to increased teacher confidence and comfort, which can directly impact student use of technology to demonstrate learning (Cradler, Freeman, Cradler, & McNabb, 2002). Current conversations also advocate the use of student work for professional development to clarify and extend teachers' own thinking about classroom practices (Kazemi & Franke, 2004). This suggests a need for educators and researchers to closely examine the digital products students create in the classroom.

Despite research in how digital tools have made an impact in practices, objectives, and learning (Beeland, 2002; Mayall & Robinson, 2009; McKendrick & Bowden, 1999), attempts to ascertain what artifacts teachers are asking students to create have been somewhat limited, though informative. Haney, Russell, Gulek, and Fierros (1998) gained meaningful insight using student drawings to examine students' perspectives on their experiences at school. The researchers were able to view concrete representations of how students saw their teachers, as well as their ideas for school reform. Borko (2004) examined how student artifacts impacted teachers' reflection of their practices. Kazemi and Franke (2004) also used student artifacts to document teacher learning. They found that the study of student artifacts increased teacher learning and informed the creation of instructional goals.

Our study sought to add to the body of research concerning what artifacts students are asked to create in technology-enhanced curriculum. As part of a statewide technology initiative, participating teachers were asked to submit student-created artifacts to a secure, online system. The purpose of this study was to analyze those digital artifacts. Our intention was to expound on current conversations about technology integration, specifically patterns of technology use in student artifacts within technology-enhanced curricula.

## RESEARCH QUESTIONS

The following research questions guided this study:

1. What elements are present in student-created digital artifacts submitted by math and science teachers in a year-long technology initiative?
2. In what ways, if any, do the digital artifacts change from the beginning to end of the year-long technology integration initiative?

In 21st-century life there is renewed emphasis on the acquisition of what have been dubbed “21st-century skills.” They are couched in, anchored to, and embedded within new and emerging technologies that emphasize an increasingly fast-paced and connected world. While reading and writing remain central literacy concerns, successfully navigating the 21st century means understanding and learning from the more “fluid and dynamic interconnectedness that is made possible by newer technology” (Adams & Hamm, 2001, p. 1).

We began our study by drawing from the Partnership for 21st Century Skills’ 21st-century literacy framework. The Partnership (P21) is a national organization with a focus on critical skills that learners must have to fluidly and successfully navigate 21st-century life. Their conceptual framework organizes these critical skills necessary in contemporary teaching and learning into four major groups: life and career skills; learning and innovation skills; core subjects and 21st-century themes; and information, media and technology skills (P21, 2009). This study focused on the latter category—information, media, and technology skill—and explored how these skills were demonstrated in digital artifacts created by students whose teachers were involved in a year-long technology integration initiative.

## METHOD

Researchers have used classroom artifacts for a wide range of purposes, from determining the effectiveness of professional development interventions to coding student drawings (Silk, Silver, Amerian, Nishimura, & Boscardin, 2009;

Wheelock, Bebell, & Haney, 2000). What constitutes an artifact varies by context (Bamford, 2003) and for the purposes of this study we define *artifacts* as systems of digital representations created by students that communicate their understanding, application, analysis, or evaluation of relevant ideas. These artifacts may be produced using text, symbols, and other multimedia elements incorporated through the application of information and communication technology.

## Sample

Math and science teachers participating in a statewide technology integration initiative were asked to select a representative student digital artifact to upload to a secure, online system at the beginning and end of the technology initiative (see Figure 1). Each upload required teachers to include

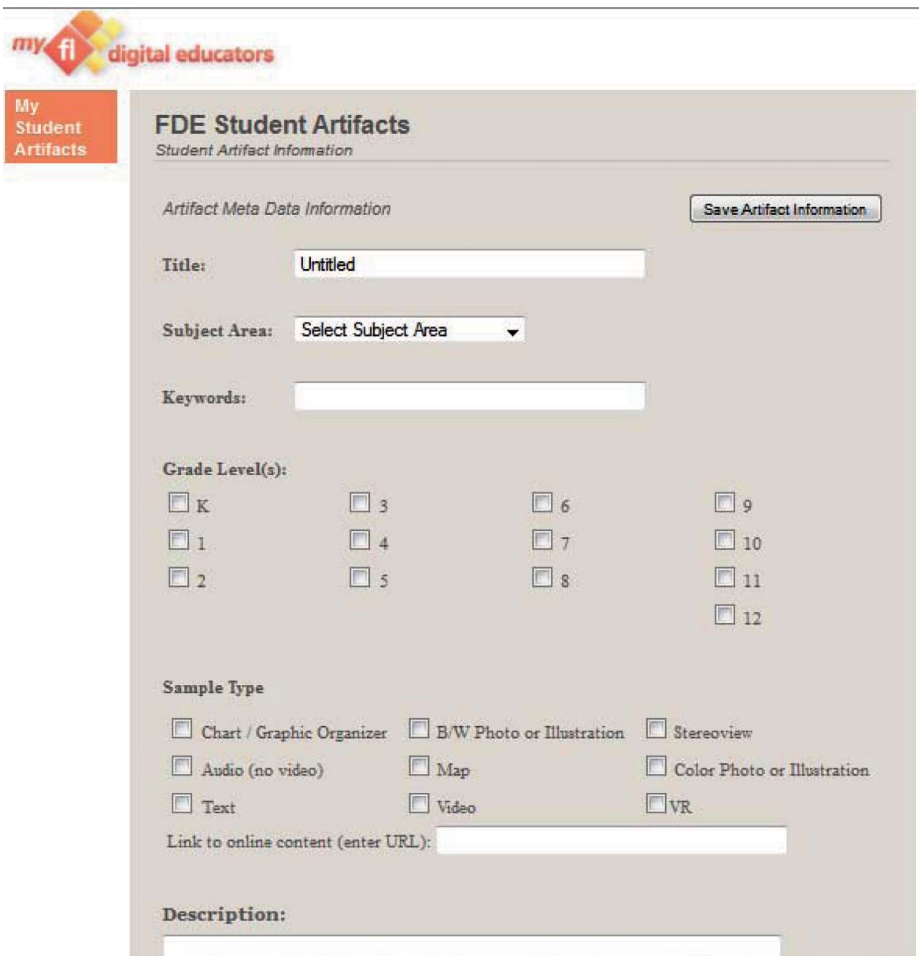
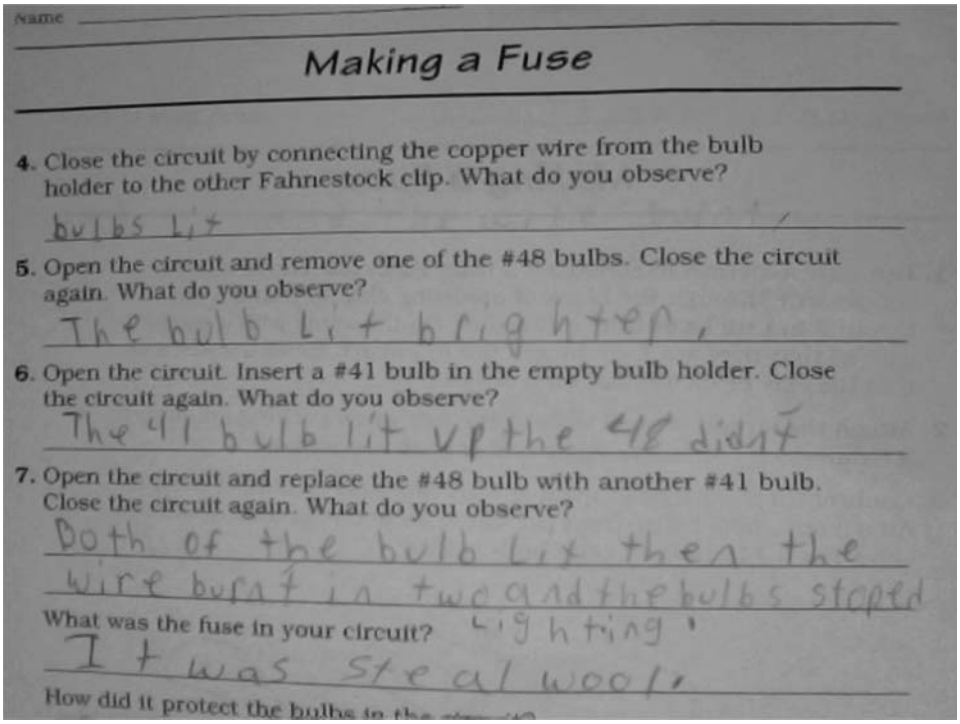



**FIGURE 1** Screenshot of online data collection system (Color figure available online).



Name

**Making a Fuse**

4. Close the circuit by connecting the copper wire from the bulb holder to the other Fahnestock clip. What do you observe?

bulbs lit

5. Open the circuit and remove one of the #48 bulbs. Close the circuit again. What do you observe?

The bulb Lit brighter,

6. Open the circuit. Insert a #41 bulb in the empty bulb holder. Close the circuit again. What do you observe?

The 41 bulb lit up the 48 didnt

7. Open the circuit and replace the #48 bulb with another #41 bulb. Close the circuit again. What do you observe?

Both of the bulb Lit then the wire burnt in two and the bulbs stoped lighting.

What was the fuse in your circuit?

It was steal wool.

How did it protect the bulbs in the ...

**FIGURE 2** Example of an artifact excluded from the data pool.

information such as subject area; grade level; keywords; and description of the context, standards, and optional additional information (see Figure 1). All submissions were time stamped to determine whether they were submitted at the beginning or end of the project. The system was closed in the middle of the year to easily identify pre- and post-submissions.

Each artifact was reviewed to ensure a math or science focus, for completeness, and for adherence to our definition of digital artifact. In many instances, for example, artifacts were excluded from analysis because teachers did not provide a description of the purpose of the artifact. In other cases artifacts were excluded from analysis because they did not adhere to our definition of artifact. Figure 2 shows an artifact that demonstrates that the student was clearly engaged in a hands-on science experience, but he/she did not create a digital product to display knowledge as required by our definition of a student artifact. One hundred fifty-four (154) artifacts (30 math and 124 science) met the inclusion criteria for this study.

## Data Analysis

We decided to use content analysis to analyze the student artifacts from our sample. Content analysis provides one way to objectively and efficiently sort large amounts of data (Krippendorff, 2004; Stemler, 2001; Weber, 1990). It allows the researchers to focus on meaningful themes and trends gleaned from the text (Krippendorff, 2004). Within the context provided by the EETT initiative, content analysis proves to be a useful way to approach the data since it fosters an exploration of multiple connections to this context (Krippendorff, 2004).

Emergent coding was used to develop the codes for content analysis. Emergent coding was necessary with our study since the coding scheme was developed after the artifacts were submitted (Neuendorf, 2002). In addition, emergent coding was used since there is no standard classification for analyzing student artifacts (Neuendorf, 2002).

The first step in the emergent coding process involved researchers individually examining a set of 15 student artifacts from a similar data pool and developing potential codes (Stemler, 2001). The researchers had extensive experience in K–12 education. Next, researchers met together with their individual codes to discuss each of the 15 student artifacts and develop a common coding system (Stemler, 2001). During this time researchers talked with other experts in educational technology and read literature related to potential codes. Next, codes were finalized and defined in an analysis rubric for use during the analysis process. Researchers used this rubric to analyze 10 additional student artifacts from the pool of 154 artifacts. Inter-rater reliability was calculated at .93. Finally, the remaining student artifacts were divided evenly between reviewers and analyzed. Descriptive statistics analysis was conducted including frequencies and percentages. *Z*-scores were computed for raw scores in the artifacts data set. They were used to compare the proportions of different categories between pre- and post-lesson plans.

## Coding Criteria

Codes developed through the aforementioned emergent process related to content, artifact purpose, cognitive demand, technology and elements, and ethical use of technology. Table 1 summarizes these codes and literature supporting them. The following sections provide more detail related to each code.

### Content Area

Content area was coded according to how it was identified by teachers when submitting the artifact. The list of math topics was modified slightly from the Common Core State Standards for Mathematics (National Council of Teachers of Mathematics [NCTM], 2000), while the list of science topics came from Florida's Next Generation Sunshine State Standards (Florida Department

**TABLE 1** Codes Used in Analysis of Student Artifacts

| Construct | Review criteria | Supporting literature |
|---|---|---|
| Content | Math topics | NCTM, 2000 |
| | Science topics | FLDOE, 2010 |
| Artifact purpose | Narrative, expository, persuasive | ISTE, 2007 |
| Cognitive demand | Cognitive demand for content area learning | Silver, Mesa, Morris, Star, & Benken, 2009 |
| Technology and elements | Student product type | Mayer, 2005; Mayer & Anderson, 1992; Pastore, 2010 |
| Artifact design elements | Resolution, font size, font type | Bix, 2002; Fleming & Levie, 1993; Knoche, McCarthy, & Sasse, 2005 |
| Ethical use of technology | Works cited | P21, 2007; ISTE, 2007 |
| | Plagiarism | ISTE, 2007 |

of Education, 2010). Researchers retrieved this information only from the Objectives and Standards sections of the student artifact submission.

### Artifact Purpose

Different performance tasks included thinking and problem-solving skills in varying levels of complexity. To determine the purpose of each artifact we looked at the teacher's description of the submission. Students that were required to tell a story (creative) were considered as having a "narrative" purpose. Students communicating information (critical thinking/problem solving) were selected as having an "expository" purpose. Lastly, students required to pose a convincing argument using content knowledge (critical thinking/problem solving) were coded as having a "persuasive" purpose.

### Cognitive Demand

To succeed in 21st-century life, students need more than basic content competency and must acquire higher levels of content knowledge (P21, 2009). To determine cognitive demand for content learning, we looked at the teacher's description of the artifact, which included what students were asked to accomplish and the artifacts that demonstrated how students engaged with the math or science content. Criteria for low and high demand tasks aligned with a study analyzing teacher lesson plans for cognitive demand (Silver, Mesa, Morris, Star, & Benken, 2009). Low demand tasks involve skills such as recalling, remembering, or applying facts/procedures, while high demand tasks involve skills such as analyzing, creating, evaluating, and being metacognitive.

### Technology and Elements

Research suggests that multimedia, a combination of verbal and nonverbal representations, can aid learning (Mayer, 2005; Mayer & Anderson, 1992; Pastore, 2010). With this in mind, the reviewers coded the technology elements used in the artifacts (product type, text, interactive elements, video, sounds, student recorded voice, images, and special effects).

### Artifact Design Elements

Using technology to effectively communicate ideas is a key skill for the 21st-century workforce (P21, 2009). Audiences need legible text, images, and video to help understand a presenter's message. Unfortunately, corporations and universities prescribe conflicting standards for many components of readability, such as font size and minimum image resolution (*Claremont Graduate University*, n.d.; Jacobs, n.d.; Office of the Board of Regents & Office of Public Affairs, 2011; *Preparing Images*, n.d.; U.S. Department of Health & Human Services, n.d.; University of Michigan, n.d.; University of Texas at Austin, n.d.).

Due to the lack of consensus around best practices and standards for presentations and readability, we combined requirements to best reflect the variability of classroom environments. The lack of information on the environments in which student artifacts were used presented another challenge in evaluating readability. The student artifact reports did not include important information about presentation equipment and room layout, which are required to accurately evaluate some components of readability. For example, the amount of ambient light in the classroom or the brightness of a projector can affect the readability of student artifacts. A low lumen (dim) projector displaying a student PowerPoint presentation using low contrasting colors can make text or images look washed out and illegible. Students presenting in a classroom with poor light control and/or a low-lumen projector must adjust their artifacts to accommodate for their presentation environment. Despite limitations, we used several guidelines to evaluate text and come up with acceptable criteria for the following characteristics: main body text size (*Claremont Graduate University*, n.d.; Jacobs, n.d.; "Office of the Board," 2011; *Preparing Images*, n.d.; StudioKSG, n.d.; University of Michigan, n.d.; UT Austin, n.d.), caption text size, contrast (U.S. Department of Health & Human Services, n.d.), minimum image resolution (*Claremont Graduate University*, n.d.; University of Michigan, n.d.; UT Austin, n.d.), and font type.

### Ethical Use of Technology/Copyright

Knowing how to ethically use and present information with technology is a key 21st-century skill (ISTE, 2007; P21, 2009). We looked for students citing information in their digital works. Different options of citing could include referencing authors, quoting, bibliography section, reference page, or a works-cited page. Artifacts incorrectly citing information still counted as having a works-cited page on our coding, since it demonstrated an "understanding of the ethical/legal issues surrounding the access and use of information" (P21, 2009). In cases of plagiarism, we looked for verifiable plagiarism where there was no original student writing (ISTE, 2007). As part of the process, the reviewers checked the information provided in artifacts using online resources. If there was an exact match to information found on a Web site, without citation, it was coded as plagiarism.

## RESULTS

One hundred fifty-four student artifacts were analyzed, of which 30 were math and 124 were science (see Table 2). Fifty-seven were pre-artifacts submitted at the beginning of the grant period and 97 were post-artifacts submitted at the end of the period. Artifacts were analyzed by trained researchers, with an inter-rater agreement of .93. Student artifacts were analyzed to determine types and elements of media used, purpose, application of ethical use of resources, and cognitive demand.

### Artifacts Semantics

The purpose of the majority of student artifacts was expository in nature (98.3% of the pre-artifacts and 95.9% of the post-artifacts.). There were no significant changes in the purpose of artifacts submitted (see Table 3). Narrative and persuasive artifacts were rarely observed.

**TABLE 2** Total Student Artifacts Submitted by Subject

| Subject | Pre (count/percentage) | Post (count/percentage) | *Z*-Value | *p*-Value |
|---|---|---|---|---|
| Math | 11 (19%) | 19 (19.6%) | −0.09 | .93 |
| Science | 46 (79.3%) | 78 (80.4%) | −0.17 | .87 |

**TABLE 3** Number of Narrative, Expository, and Persuasive Artifacts

| Artifacts semantics | Pre (count/percentage) | Post (count/percentage) | *Z*-Value | *p*-Value |
|---|---|---|---|---|
| Purpose/narrative | 3 (5.2%) | 6 (6.2%) | −0.26 | .80 |
| Purpose/expository | 57 (98.3%) | 93 (95.9%) | 0.82 | .41 |
| Purpose/persuasive | 3 (5.2%) | 8 (8.2%) | −0.70 | .48 |

**TABLE 4** Cognitive Demand for Content

| Cognitive demand for content | Pre(count/ percentage) | Post(count/ percentage) | *Z*-Value | *p*-Value |
|---|---|---|---|---|
| High | 5 (8.6%) | 20 (20.6%) | −1.97 | .05 |
| Low | 53 (91.4%) | 77 (79.4%) | 1.97 | .05 |

## Cognitive Demand for Content

Although there were not significant changes in high or low cognitive demand, there was an increase in high cognitive demand and decrease in low cognitive demand from pre-submission to post-submission (see Table 4). However, the majority of student artifacts were low cognitive demand (91.4% pre- and 79.4% post-artifacts). Only 20.6% of the post-artifacts were high cognitive demand. As can be gleaned by the $p$ values, the differences between pre- and post-submissions were approaching significance.

## Media Type

The majority of the artifacts (45.4%) submitted by teachers were PowerPoint presentations (see Table 5). Other submissions included movies (19.6%) and images (14.4%). There was a significant decrease in the creation of print documents ($p < .01$). Comic strips, blogs, vlogs, glogs, and interactive games were rarely observed.

## Elements Used in Media Type

A majority of the pre-artifacts included text (84.5%) and images (62.1%) (see Table 6). The use of text remained consistent in the post-artifacts submitted

**TABLE 5** Media Types Found in Student Artifacts

| Media type | Pre (count/percentage) | Post (count/percentage) | *Z*-Value | *p*-Value |
|---|---|---|---|---|
| Blog | — | 1 (1.0%) | –0.76 | .44 |
| Vlog | — | — | — | — |
| Glog | — | 3 (3.1%) | –1.35 | .18 |
| Web site | 1 (1.7%) | 2 (2.1%) | –0.17 | .86 |
| Interactive game | — | 1 (1.0%) | –0.76 | .44 |
| PowerPoint | 18 (31%) | 44 (45.4%) | –1.77 | .08 |
| Movie | 8 (13.8%) | 19 (19.6%) | –0.92 | .36 |
| Print document | 15 (25.9%) | 6 (6.2%) | 3.47 | .00 |
| Podcast | 2 (3.4%) | 2 (2.1%) | 0.49 | .62 |
| Graphic organizer | — | 4 (4.1%) | –1.56 | .12 |
| Image | 10 (17.2%) | 14 (14.4%) | 0.47 | .64 |
| Comic strip | — | — | — | — |
| Spreadsheet | 5 (8.6%) | 5 (5.2%) | 0.83 | .41 |
| Other | 2 (3.4%) | 3 (3.1%) | 0.10 | .92 |

**TABLE 6** Number of Elements Used in Media Type

| Elements used in media type | Pre (count/ percentage) | Post (count/ percentage) | *Z*-Value | *p*-Value |
|---|---|---|---|---|
| Text | 49 (84.5%) | 90 (92.8%) | –1.64 | .10 |
| Video | 5 (8.6%) | 13 (13.4%) | –0.90 | .37 |
| Sounds | 4 (6.9%) | 22 (22.7%) | –2.55 | .01 |
| Interactive elements | 4 (6.9%) | 13 (13.4%) | –1.25 | .21 |
| Images | 36 (62.1%) | 80 (82.5%) | –2.83 | .00 |
| Student recorded voice | 10 (17.2%) | 18 (18.6%) | –0.22 | .83 |
| Special effects | 10 (17.2%) | 31 (32.0%) | –2.02 | .04 |

(92.8%). A small number of artifacts included other elements such as sounds (6.9%) and special effects (17.2%). There was a significant increase ($p < .01$) in the use of images (82.5%), as well as in sounds (22.7%) ($p < .05$), and special effects (32%) ($p < .05$).

## Artifact Design Elements

Design font size in the content (16–36+) showed significant increase in appropriate size selection (55.7%) ($p < .05$) (see Table 7). In addition, design resolution saw a significant increase ($p < .01$) where high resolution images were selected (86.6%) most of the time.

## Ethical Use of Technology/Copyright

Post-artifact submissions indicated a significant decrease ($p < .01$) in plagiarism (see Table 8). A small percentage of artifacts included works cited in some way (15.5% pre- and 14.1% post-artifacts).

# DISCUSSION

## Content Area

Teachers submitted four times the amount of codable science artifacts as math artifacts. While more science teachers participated in the grant, there

**TABLE 7** Design Elements in Student Artifacts

| Design elements | Pre (count/ percentage) | Post (count/ percentage) | *Z*-Value | *p*-Value |
|---|---|---|---|---|
| Design contrast (good1/bad0) | 39 (67.2%) | 64 (66.0%) | 0.15 | .88 |
| Design font size content (16–36+) | 20 (34.5%) | 54 (55.7%) | –2.56 | .01 |
| Design font size captions (12–24+) | 9 (15.5%) | 24 (24.7%) | –1.35 | .18 |
| Design font type (block1/cursive0) | 45 (77.6%) | 77 (79.4%) | –0.27 | .79 |
| Design resolution (high/low) | 38 (65.5%) | 84 (86.6%) | –3.11 | .00 |

**TABLE 8** Number of Artifacts Indicating Ethical Use of Technology

| Ethical use of technology/copyright | Pre (count/ percentage) | Post (count/ percentage) | $Z$-Value | $p$-Value |
|---|---|---|---|---|
| Plagiarism | 7 (12.1%) | 1 (1.0%) | 3.02 | .00 |
| Works cited | 9 (15.5%) | 14 (14.4%) | 0.19 | .85 |

are other possible explanations for the large difference between math and science submissions. The disparity in artifact submissions could indicate that teachers do not ask students to use technology as often in math class. Mathematics teachers have reported lower levels of technology use when compared to teachers in other subject areas (Bebell, Russell, & O'Dwyer, 2004). Traditional mathematics education heavily depends on using pen and paper and direct instruction (Pierce & Ball, 2009). Many teachers using technology in mathematics have to make dramatic alterations to their teaching practices to use technology (Pierce & Ball, 2009), which could explain the lower amount of mathematics student artifacts. The dependence on pen and paper in many math lessons could hinder teachers from exploring other technologies. Math teachers in Florida are also under pressure to ensure high student performance on the state standardized tests. Standardized tests arguably reward more traditional drill-and-practice activities than novel uses of technology (Street, 2008; Tan & Guo, 2010).

Math is an interdisciplinary subject that should be presented in a meaningful environment to aid learning. Coming up with situational uses of math concepts can be time consuming and challenging to create compelling scenarios. Technology can help provide an efficient means for students to create authentic (Oblinger, 2003) artifacts that demonstrate subject mastery. We recommend that teachers collaborate with other mathematics teachers to create easily replicable, dynamic, and authentic application of math concepts. Collaborating will increase creativity of student assignments and save time by allowing teachers to share resources and split up work.

## Artifacts Semantics

That the majority of the artifacts submitted were expository in nature may suggest a connection with the educational push for standardized assessments. Most questions in standardized tests ask students to glean information from the text, illustrations, and figures. Problem solving and gaining information are given priority over other areas. Within technology integration initiatives, privileging certain skills over others may risk limiting learning to a "set of de-contextualized skills" (Evans, 2005, p. 2). Technology is more than the use of tools; it is constitutive of our sociocultural landscapes (Ananiadou & Claro, 2009; Evans, 2005). We recommend an increase of student creation of artifacts for other purposes (such as narrative and persuasive) to foster the holistic development of all abilities (Ananiadou & Claro, 2009).

## Cognitive Demand for Content

Part of the demands of a 21st-century life includes higher level cognitive processes (ISTE, 2007; P21, 2009) instead of decontextualized sets of skills (Evans, 2005). Despite increases in high cognitive demand, most of the artifacts in this study were limited to factual recall and communication, which are classified as low cognitive demand (Silver et al., 2009). This could be tied to the artifact purpose, which was mostly expository. Teachers seem to be asking students to present information on the content that was learned during instruction. In math artifacts in particular, this result is not surprising, as research has found little variation in instructional tasks that tend to reflect low cognitive levels (Silver et al., 2009). While presenting factual information does not foster high levels of cognition, it could provide a starting point to higher level processes.

The few artifacts that did reflect high cognitive demand included data analysis and explanation. Many of the high cognitive artifacts were videos where students explained processes and provided rationale for problem solving, thus demonstrating analysis and evaluation (Silver et al., 2009). Schoenfeld (1992) recommended a renewed focus on seeing students as flexible thinkers who seek solutions, explore patterns, and formulate conjectures. We recommend that teachers build on what they already ask students to do by including assessments that reflect high-level thinking skills. For example, teachers could ask students to provide rationale for the information presented, including discussion questions and a reflection of their work.

## Media Type

An increased use of technology has emphasized the expectation of working with text and images (Avgerinou, 2001; Callow, 2005; Mayall & Robinson, 2009; Noble, 2004). Many teachers are now expected to have knowledge of presentation software such as PowerPoint to teach and communicate ideas. Such software has become part of the mainstream. It is not surprising that the majority of artifacts submitted for the EETT grant were PowerPoint presentations and that there was a decrease in the creation of print documents. While knowledge of presentation software is useful, we recommend teachers step outside of the mainstream and include other software and technologies that have yet to become commonplace. We argue in favor of other technologies and media types that students increasingly engage with outside of school, such as videos, applications, social networking, and others. New technologies have the potential to change the nature of the classroom (Mishra &

Koehler, 2006) and are used to establish experiential, interactive, and authentic learning (Oblinger, 2003).

## Elements Used in Media Type

The presence of sounds, images, and special effects in student artifacts showed significant increases from pre-submission to post-submission. The reduction in print document artifacts can help explain the increases in sounds, images, and special effects, since other student artifacts, such as movies, usually include these elements. The increases of multimedia elements are positive for student artifacts, since multimedia facilitates learning effectively (Mayer, 2005; Mayer & Anderson, 1992; Pastore, 2010). The increase in multimedia elements also can indicate a rise in the available choices for students to construct ideas. Technology provides an effective and efficient way for students to express their understanding in many different mediums (Tomlinson & McTighe, 2006).

There were no statistically significant changes of interactive elements in student artifacts. Interactive elements allow for greater interaction between artifacts and learners, which increases active learning. Active learning leads to higher engagement and learning outcomes (Prince, 2004). We recommend that teachers can increase interactive elements in student artifacts by assigning more projects using Web 2.0 tools. Many of these online tools are free to use and involve high levels of interactive elements and are often user friendly.

## Artifact Design Elements

There were impressive gains in students creating artifacts using appropriate font size and higher resolution. However, a third of student artifacts had low contrast elements and almost half had legibility issues. Such issues in these categories hinder a student's ability to communicate with others. We recommend that teachers focus student attention on these areas by adopting or adapting existing standards (*Claremont Graduate University*, n.d.; Jacobs, n.d.; "Office of the Board," 2011; *Preparing Images*, n.d.; StudioKSG, n.d.; University of Michigan, n.d.; UT Austin, n.d.) for font size and contrast incorporated into assessment. For instance, teachers could provide students with exemplars of what they consider appropriate and inappropriate design elements.

## Ethical Use of Technology/Copyright

Twenty-first century students are asked to use technology to demonstrate problem solving, critical thinking, and creativity (ISTE, 2007; National Council of Teachers of English [NCTE], 2008). An important part of this includes how to ethically use and present such information using technology tools (ISTE, 2007; NCTE, 2008; P21, 2009). It is pertinent to ascertain the extent to which ethical considerations are present in student created artifacts. In this study, because of the nature of some of the artifacts and lack of context in which to place them, only those artifacts with verifiable instances of plagiarism and those that provided explicit references to other sources were included in the analysis. Because of these limitations, only 31 artifacts inform this section. According to the findings, while there was a significant decrease in cases of verifiable plagiarism, less than 15% of the submissions included attribution. While we cannot make justifiable claims from these findings, they provide certain insights that invite more discussion. Such a low percentage emphasizes the need to increase awareness of ethical considerations when students mix and remix products (NCTE, 2008).

## LIMITATIONS

Examining student artifacts outside of their original context to determine patterns of technology use presents several limitations. We are unable to make comments or inferences on teachers' instructions or guidance, which could serve to enrich the findings. The study is limited by a small sample size due to limitations provided by the inclusion criteria and the nature of the artifacts submitted. Results are also limited by the quality and level of detail of both the information submitted by teachers and the artifacts themselves. Since the duration of the study was so long there are also possible maturation threats. Students could exhibit increases in media elements used and media types since they are more widely used and not because of EETT interventions. Finally, the patterns and information gleaned from this study can serve to inform current practices and future research, but lacks generalizability.

We have addressed these limitations in several ways. First, we decided on specific inclusion criteria because that would help yield the most relevant and complete results for our research questions. Second, we defined our coding criteria according to the literature in related fields including educational technology and literacy. Finally, the researchers participated in extensive review and coding of the data and inter-rater agreement work.

## IMPLICATIONS

Many learners of the 21st century actively consume, create, and negotiate content using technology that is ever transforming and increasingly emphasizing global connectivity and collaboration with others (ISTE, 2007). Content is received and delivered using various modes of meaning-making and representations that include print, visuals, audio, and others (Hinchman, Alverman, Boyd, Brozo, & Vacca, 2003), which can aid learning (Mayer, 2005; Mayer & Anderson, 1992; Pastore, 2010). This can include watching television, Internet surfing, and downloading applications on a mobile device. Today's learners are constantly moving through fluid spaces where they can learn and create at their leisure. Ongoing research, conversations, and technological innovations have impacted policy and funding (Davies, 2011; Kozma & Anderson, 2002), influencing what is taught and how (Leu & Kinzer, 2000). Such initiatives have made technology an important aspect of teacher education programs (Gronseth et al., 2010; Mims, Polly, Shepherd, & Inan, 2006; Mishra & Koehler, 2006; Niess, Van Zee, & Gillow-Wiles, 2010).

An increased use of technology has emphasized the need for learning to freely use information and imagery to create products and technology tools for and in the K–12 classroom. While the research in educational technology has explored whether digital tools have made an impact in practices, objectives, and learning (Beeland, 2002; Mayall & Robinson, 2009; McKendrick & Bowden, 1999; Messaris, 1994; Rakes, Rakes, & Smith, 2007), attempts to document what digital tools and elements students use in artifact creation have not been prevalent. More conversations and research concerning students' use of technology and nonlinguistic representations (Jewitt, 2008) are needed to explore patterns of artifact production that could enhance our understanding of what teachers are asking students to do and what counts as acceptable use of technology in technology-enhanced curricula. For example, rubrics can offer insight into what teachers are expecting of student digital work.

Our study contributes to the literature on student use of technology in science and mathematics classrooms by examining the technology elements in student artifacts submitted by teachers involved in a year-long technology integration initiative. It identifies areas of significant improvement in student use of technology, as well as highlights areas for improvement. There has been an increase in multimodal artifacts which demonstrates an enrichment of traditional print-based productions. It is possible that this study can also inform professional development initiatives where technology is the focus.

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