

Exploring the Role of Elementary Teachers' TPACK in the Adoption of 1:1 Computing Across Subject areas

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This study examines the role that technological pedagogical content knowledge (TPACK) plays in elementary teachers' adoption of 1:1 computing for instruction across the subject areas of mathematics, science, English language arts, and social studies. In particular, the research explored whether teachers' self-reported TPACK moderated the relationship between teachers' perceived ease of use (PEOU) and perceived usefulness (PU) of 1:1 computing for instruction in each of the subject areas. The results indicated that TPACK was a significant moderator of the relationships between PEOU of 1:1 and whole-class science instruction, individualized science instruction, and individualized mathematics instruction. TPACK was also a significant moderator of the relationship between PU of 1:1 and the use of 1:1 for whole-class science instruction and individualized mathematics. TPACK was not a significant moderator of any of the relationships between PEOU or PU and instruction involving 1:1 in the subjects of English language arts or social studies. These findings suggest that TPACK can strengthen elementary teachers' adoption of 1:1 for instruction in mathematics and science but did not support this notion in English language arts or social studies.

Keywords: One-to-one computing, technological pedagogical content knowledge, TPACK, instruction, elementary school

INTRODUCTION

The Office of Educational Technology's national technology plan discusses one-to-one computing as an opportunity for establishing equity among students (King & South, 2017). The use of technology for teaching and learning continues to grow in classroom use in the United States and worldwide. Many schools have adopted programs that allow for 1:1 computing technology. The sheer number of technology tools available for classroom use is impossible to keep up with, and the job duties required of a teacher make time for exploration minimal. Many elementary school teachers teach multiple subjects adding another layer of complexity. The Technological Pedagogical Content Knowledge TPACK model described by Koehler & Mishra (2009) represents an interaction between content, pedagogy, and technology and is commonly used to study the integration of technology. TPACK is often used as a research topic. A search on Google Scholar using the term TPACK results in over 24,500 results.

This study examines the role that TPACK plays in elementary teachers' (teachers) adoption of 1:1 computing (1:1) for instruction in the subject areas of mathematics, science, English language arts, and social studies. As with many teaching tools, the instructor's acceptance and ability to implement effective practices will influence the overall outcome. This research examines whether TPACK served as an external variable, as described by Davis et al. (1989) in the Technology Acceptance Model (TAM). A moderator analysis was conducted to examine whether TPACK altered the relationships among teachers' perceived ease of use and perceived usefulness of 1:1 for instruction in mathematics, science, English language arts, and social studies. In doing so, the researchers examined two forms of instruction involving 1:1 (a) whole-class and (b) individualized.

The research questions were as follows:

1. To what degree do teachers' perceived ease of use of 1:1 and perceived usefulness of 1:1 predict their reported use of 1:1 for instruction in mathematics, science, English language arts, and social studies?
2. Is the relationship between teachers' perceived ease of use of 1:1 and their reported use of 1:1 for each subject moderated by teachers' reported TPACK?
3. Is the relationship between teachers' perceived usefulness of 1:1 and their reported use of 1:1 for each subject moderated by their reported TPACK?

The results of this study can help educational leaders and policymakers to understand the role that TPACK plays in influencing elementary school teacher's adoption and usage of 1:1 computing for elementary school instruction across different subject areas.

THEORETICAL FRAMEWORK

The present study utilized the Technology Acceptance Model (TAM) as a theoretical lens for examining teacher's adoption of 1:1 across the subject areas. The TAM was developed to evaluate the market potential for emerging computer-based applications in the mid-1980s (Davis & Venkatesh, 1996) and continues to be widely applied as a framework for examining technology adoption in the research literature. For example, Walker et al. (2019) employed the TAM to study practicum teachers' use of mobile technology. Other recent applications of the TAM include an examination of teachers' acceptance of an augmented reality tutoring system (Ibili et al., 2019) and teachers' adoption of a technology-based early language and literacy curriculum (Xie et al., 2019). The TAM posits that two constructs, Perceived Usefulness (PU) and Perceived Ease of Use (PEOU), influence a person's Behavioral Intention (BI) to use technology and that BI influences actual system usage of the given technology (Bogazzi, 2007). Davis (1989) defined PU as "the degree to which a person believes that using a system would enhance

his or her job performance" and PEOU as "the degree to which a person believes that using a system would be free of effort" (Davis, 1989, p. 320). Davis et al. (1989) noted that external variables could influence technology usage by providing a "bridge between the internal beliefs, attitudes, and intentions represented in the TAM and the various individual differences, situational constraints, and managerially controllable interventions impinging on behavior" (Davis et al., 1989, p. 998).

The TPACK framework is an extension of Shulman's (1987) concept that pedagogical content knowledge should be infused with technology into the practice of teaching. TPACK describes "an understanding that emerges from an interaction of content, pedagogy, and technology" (Koehler & Mishra, 2009, p.17). TPACK (Figure 1) is represented as the intersection of the three knowledge dimensions of technology, pedagogy, and content.

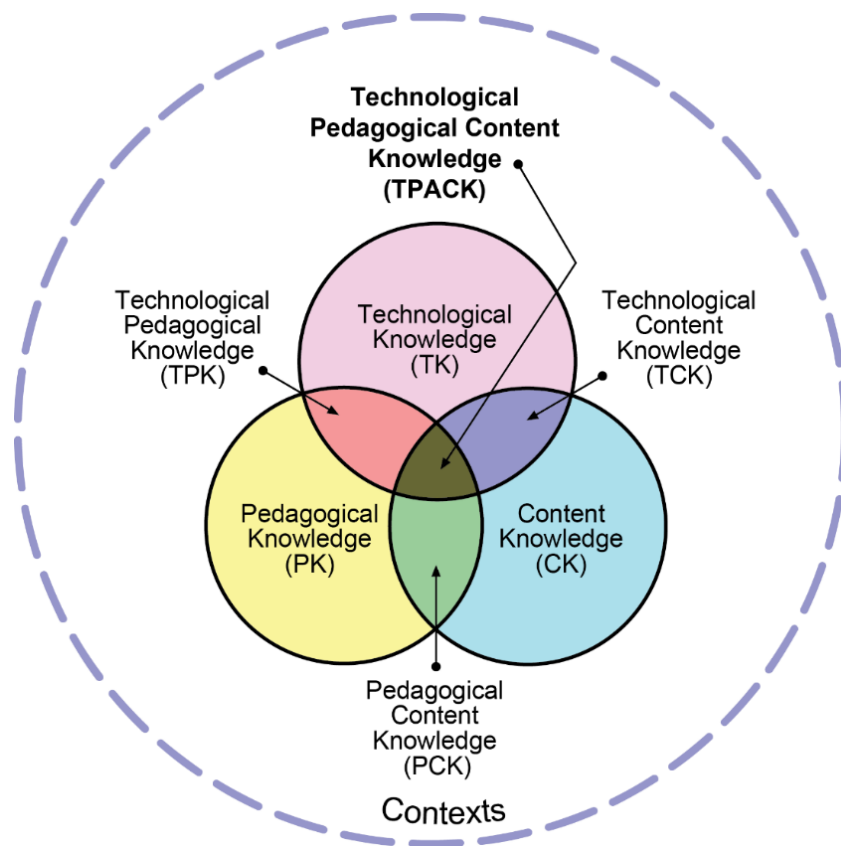


Figure 1. TPACK model

TPACK is more than just the sum of its parts. When studying TPACK and mathematics instruction (Groth et al., 2009) described instruction using TPACK implies that teachers must engage with content, pedagogy, and technology in tandem to develop knowledge of how technology can help students learn specific concepts.

LITERATURE REVIEW

One-to-one computing has created a new learning ecology (Spires et al., 2012). These authors state that if each student and teacher has a mobile learning technology device and

access to the Internet, the conditions for learning are fundamentally altered as students have ready access to vast amounts of information and tools for communication, productivity, and creativity. Lindqvist (2015) observed students worked more creatively with 1:1 computing available to them. Students could access information with greater ease, take notes to remain engaged in learning. The researcher also reported teachers found it easier to structure their planning and teaching, add a professional touch to their instructional materials, and communicate more freely with their colleagues.

Teacher implementation of 1:1 computing is time-consuming. Zheng et al. (2016) found teachers reported they needed two years to adapt to the new teaching style of 1:1 and classes may have had to divert time from academic content to teach pre-requisite computer skills. Crichton et al. (2012) found that experienced teachers' lack of familiarity with devices contributed to trepidation; moreover, personal comfort with technology did not translate into comfort with implementing technology in their classrooms. This statement supports that both PEOU and PU are important constructs for teachers' use of technology for learning. The availability of professional development for teachers is key to implementing a 1:1 program (Powers & Musgrove, 2020; Spires et al. 2009, Vu et al.,2019).

Although the current study focuses on teachers, the whole system they work in needs to support the change in 1:1 classrooms. Each 1:1 computing initiative implementation can look different in each school, grade level, and subject area, even within the same school or district. Awareness of the influence of pedagogy on 1:1 technology integration is vital for those at various levels in schools and districts (Parrish & Sadara, 2020.) For each subject and grade level, 1:1 computing devices can play a different role in teaching the content according to school-wide culture and each educator's teaching style.

In this study, we focused on the role TPACK plays in influencing elementary school teacher's adoption and usage of 1:1 computing for instruction in whole class and individualized mathematics, science, English language arts, and social studies. Tomlinson (2012) described individualized or differentiated instruction as the effort a teacher makes to "address student variance" among learners in a classroom. The well-prepared educator in the 1:1 classroom can be responsive to their students' needs, help them navigate the information they find, and leverage technology as a means for individualizing the learning experience (Spires et al., 2012).

1:1 IN THE MATHEMATICS CLASSROOM

The national council of teachers of mathematics (2015) supports the strategic use of technology in teaching and learning of mathematics and the use of digital and physical tools by students and teachers in thoughtfully designed ways and at carefully determined times so that the capabilities of the technology enhance how students and educators learn. Warschauer et al. (2011) found that efficient and effective use of technology could boost academic achievement when students have regular daily access to laptops. Urbina and Polly (2017) observed third-grade mathematic teachers using Chromebooks with a focus on TPACK. They felt that technology-supported students' mathematics learning prepared them for their future where technology will be important. All teachers in this study used technology to display, model, and discuss strategies to solve mathematics problems. One teacher commented that "understanding when and how to use technology effectively is as important as understanding the technology itself" (Urbina & Polly, 2017, p. 8). This statement shows the importance of a sound pedagogical foundation when integrating technology into the subject matter. As educators prepare the world's future workforce, we must strive to foster effective strategies in even our youngest students. Cicconi (2014) studied math in lower elementary schools and found that using technology to engage students in collaborative endeavors deepens their understanding of mathematics by

offering rigorous learning through relevant projects with authentic audiences. The researcher says that Voki, Vodcasts, and VoiceThread offer children live audience members with whom they can share knowledge and expound insight. Technology simultaneously ushers in creating, analyzing, and applying through collaboration into the classroom while generating greater enthusiasm for learning mathematics. Li et al. (2019) researched mathematics teachers' TPACK development in Beijing, China, and found to increase TPACK, teachers should be challenged about their ideas regarding teaching and technology and encouraged to employ innovative teaching approaches. This research supports the concept that having the technology available is only a part of the success of 1:1 mathematics integration. A variety of support factors and time to reinvent instruction is necessary to increase TPACK in teachers.

1:1 IN THE SCIENCE CLASSROOM

Science includes concepts that can be difficult to teach and comprehend solely with text or static images. Educational technology that can incorporate a broader range of representations such as video, animations, and interactive models is increasingly common. In the science classroom, 1:1 can have a positive impact by offering teachers new tools for developing more engaging lessons and assisting students in making real-world connections in the science curriculum. Science teachers often emphasize the importance of analytical skills, for example, the idea of taking two pieces of information from two different sources and relating them to one another.

TPACK, for science teachers and mathematics teachers at least, may depend partly on the use of specific technology. Jang and Tsai (2012) found that elementary teachers who used interactive whiteboards had significantly higher TPACK than those who did not. Interestingly, they also found that science teachers had higher TPACK than math teachers. A relatively large (n=722) analysis of pre-service science teachers in Turkey (Kadioğlu et al., 2020) supported a five-dimensional construct for measuring their TPACK (ICT-TPACK) that included planning, designing, implementing, ethics, and proficiency.

How science teachers use technology is important, and strong pedagogical knowledge is a necessary precursor. For example, pre-service science teachers may use technology to motivate students rather than incorporate it into more sophisticated science pedagogies like inquiry learning or concept construction (Tanak, 2020). Unsophisticated use of technology may not be limited to inexperienced teachers; a study of both pre-service and in-service teachers in Taiwan found that they both displayed TPACK-P (practical) knowledge at levels two and three out of four. Still, most were only applying it at level one (Jen et al., 2016). These findings were supported by a study of lesson plans after a lengthy technology integration program for science teachers (Pringle et al., 2015). While their use of technology increased, their usage of science-specific software or incorporation of scientific inquiry was disappointing. On the other hand, another study in Taiwan showed that more experienced math and science teachers had significantly higher TPACK than their less experienced peers (Jang & Tsai, 2012).

1:1 IN ENGLISH LANGUAGE ARTS

As students are increasing their use of technology, their English language arts (ELA) teachers' knowledge of technology has changed to meet students' academic and technological demands (Elam et al., 2007). Simultaneously, the field of language arts and literacy has broadened its traditional definition of language arts and literacy skills (reading, writing, listening, and speaking) to include multimodal, semiotic modes as a means for interpretation and meaning-making. These multimodal sources of information, referred to as *New Literacies*, use linguistic, visual, audio, gestural, and spatial modes (Tan & Zammit, 2018) found in print, websites, blogs, and films to help students make sense of new

information (Cameron & Panović, 2014). Adopting new literacies can challenge ELA teachers using 1:1 computing to adapt both pedagogy and technology to the new literacy approach to ELA. The dramatic shifts occurring in language and literacy education because of new literacies skills have also impacted how these skills have been assessed, particularly in TPACK.

The use of 1:1 computing can help create a learning environment that supports the new vision of the ELA classroom. Students taught to use metalanguage in the classroom can explain relationships between ideas and concepts used to represent meaning during instruction. According to Geoghegan et al. (2013), classroom lessons that embrace metalanguage encourage teachers and students to engage in conversations about how language works within multimodal texts. Teachers encourage students to attend to specific aspects of texts (e.g., words, images, symbols) to supplement their comprehension. Teacher-student discussions focus on the use of how differing sentences, types of texts, discourses, and other symbolic representations impact the readers' understanding and demonstrate how language and symbols can be used to construct texts, knowledge, and power. One-to-one computing can provide the tool for multimodal, new literacies' learning and concentrate on explicitly teaching their students to use the correct metalanguage or vocabulary to demonstrate comprehension of content knowledge found in multimodal texts.

Many studies show a relationship between 1:1 computing devices such as laptops positively affecting the literary response, analysis, and writing strategies. According to O'Dwyer et al. (2005, p. 7), "students who reported using technology more frequently at school to edit their papers were more likely to have higher total English Language Arts (ELA) test scores and higher writing scores on the Massachusetts Comprehensive Assessment System than students who used computers to edit papers less frequently or not at all." Many studies suggest that 1:1 laptops are frequently used in ELA classes for writing or editing papers, conducting research, collaborating on assignments, reading analysis, and using various online tools and applications. ELA Teachers reported to Suhr et al. (2010, p. 22), "the most common uses of laptops were for writing and research on the Internet, through sources such as *NetTrekker* or Google search engines. Additionally, teachers reported that their students regularly created multimedia presentations using PowerPoint, Keynote, or iMovie". These findings suggest that laptop use is a valuable tool in the English Language Arts classroom and can be used to shift to new literacies.

1:1 IN THE SOCIAL STUDIES CLASSROOM

The epic *No Child Left Behind Act* (US Department of Education, 2002) failed to include social studies among the subjects for which states were required to set standards and develop testing systems. To assess the impact of this policy on elementary social studies instruction, Bailey et al. (2006) conducted a study on time spent on teaching elementary social studies. The researchers also looked at the use of instructional strategies, including the integration of technology. The data analysis revealed that elementary pre-service teachers in Title I schools spent far less time teaching social studies than the amount of time allocated by the county and only a small percentage of the time mandated by the state. The data also revealed that social studies teaching strategies were primarily limited to textbook readings and questions and vocabulary definition work. When technology was involved, it was mainly facilitated by paraprofessionals.

Historically, educational technology has been seldom used in elementary social studies classrooms. When used, technology integration has often been limited to software games like *The Oregon Trail* or *Where in the World is Carmen Sandiego* (Swan & Hofer, 2008). Such games can be entertaining but neglect the role of TPACK for educationally profitable technology integration in elementary school content areas (Byker, 2014). Byker (2014)

noted, "There is a gap in the literature empirically documenting the integration of instructional technology in elementary social studies methods courses" (p. 107). This researcher conducted a study of pre-service teachers' perceptions of their utilization of the software *Timeliner* in an elementary social studies methods course. The study's findings indicated that the participants were enthusiastic about engaging with the software but did not make connections to the purpose of the activity in relation to the *Timeliner* technology. The findings also suggested that the participants tended to dissociate technological knowledge from pedagogical knowledge rather than connect the two. Considering these findings, the author contended, "Preparing future elementary teachers to connect social studies content and skills with technology necessitates the integration of technology into teacher preparation methods courses" (p. 106). This example shows how the implementation of 1:1 computing devices across subject areas can shift teachers' use of traditional models towards creating authentic, open-ended tasks relevant to students' needs and interests, concurrently teaching them 21st-century skills and preparing them for their future.

Elementary teachers typically teach multiple subjects and adopt 1:1 computing differently in different subject areas. Using the TAM as a theoretical framework, this study explored if TPACK played a moderating role and might influence the relationship between PU or PEOU in different subject areas. Using TPACK may help focus on the importance of building instructional strategies on the foundation of pedagogy. Examining these relationships may benefit school leaders when exploring how to support and encourage teachers to use 1:1 computing for instruction across subject areas.

METHODS

PROCEDURES

The researchers developed a self-report questionnaire to gather data for this study. The survey was administered electronically utilizing *Qualtrics* software via an email invitation that included a link to the questionnaire. A pilot version of the survey was administered to 22 teachers (current and former) to get feedback and establish face validity. Feedback from the pilot participants was used to refine and clarify the survey items. Information collected included teacher background information, adapted TAM components (perceived ease of use, perceived usefulness, and frequency of use 1:1 of computing), and variables that may moderate teachers' technology adoption derived from the research literature, including TPACK. The final version of the survey contained 22 items, although not all of them were utilized in this analysis.

PARTICIPANTS

The study participants were second through fifth-grade teachers from a large Florida school district, one of the largest in the United States. The district is comprised of 136 elementary schools and approximately 96,000 kindergarten through fifth-grade students. Two forms of data collection were used for this study. The first was a teacher self-report survey, in which a total of 333 teachers participated. It should be noted that only teachers who indicated on the survey that they taught students in a 1:1 environment were selected for inclusion in this analysis (n=242). The institutional review board approved this research at the researchers' university and in the school district.

Description of the Survey Participants. In the survey, 23 of the teachers indicated they were male, 208 female, and eight responded that they preferred not to answer the question about gender. The participants' reported years of teaching experience ranged from 1 to 43 years, with an average of 14.95 years. The participants reported teaching a variety

of subjects including English Language Arts ($n=200$), Mathematics ($n=194$), Science ($n=183$), Social Studies/History ($n=150$), Physical Education ($n=7$), Music ($n=3$), Art ($n=1$), and other subjects ($n=14$). Fifty-five percent of the participants held a bachelor's degree, 38% a master's, 3.8% a specialist's degree, and 0.8% a doctorate, while 1.2% responded with "other" degree. The participants represented a variety of grade levels, as summarized in Table 1.

Table 1. *Descriptive Statistics for Teachers' Grade Level Taught of Survey Participants*

Subject	Frequency
2 nd grade	49
3 rd grade	58
4 th grade	68
5 th grade	79
Other	04
Total respondents	258

Participants were asked to respond to the following survey item: "In the classes I teach, all of the students have access to a school-issued laptop, tablet, or another mobile computing device." A total of 38 responded that these devices were available "at all times throughout the school day, and may take it home," 100 "at all times throughout the school day, but may not take it home," and 102 "while in my classroom only."

THE INSTRUMENTS

Instructional Use of 1:1. On the survey, teachers were asked, "How frequently do you use 1:1 computing in each of the following ways for individualized instruction?" Later, they were asked the same question regarding their use of 1:1 with their students for whole-class instruction. After these questions, participants were presented with four options which included: (a) I engage students in English / language arts lessons; (b) I engage students in mathematics lessons; (c) I engage students in science lessons; and (d) I engage students in social studies/history lessons (Powers and Musgrove, 2020). The items were adapted from Davis' (1989) actual system usage and measured on a 5-point Likert scale with endpoints ranging from "extremely frequently (5)" to "extremely infrequently (1)." These eight survey items were recorded and used to measure the frequency of use of 1:1 for individualized and whole-class instruction in each of the subject areas. The rationale for recoding the items was to deal with the issue that a teacher may have reported any level of frequency of use of 1:1 in a subject that they did not report currently teaching. Therefore, each item was recoded to include only teachers that reported teaching a given subject in the demographic/background section of the survey. Descriptive statistics for these items are presented in Table 2.

Table 2. *Descriptive Statistics for Teachers' Reported Frequency of Use of 1:1 Computing for Instruction Across Subject Areas*

Survey Item	<i>n</i>	<i>Min</i>	<i>Max</i>	<i>Mean</i>	<i>SD</i>
Whole-class mathematics	180	1.00	5.00	1.76	0.79
Whole-class science	169	1.00	5.00	2.02	0.86
Whole-class English language arts	200	1.00	5.00	1.82	0.81
Whole-class social studies	139	1.00	5.00	2.17	0.87
Individualized mathematics	172	1.00	5.00	1.88	0.92
Individualized science	166	1.00	5.00	2.04	0.91
Individualized English language arts	177	1.00	5.00	1.95	0.95
Individualized social studies	134	1.00	5.00	2.22	0.96

Perceived ease of use and usefulness. Scores for the variables teachers' reported perceived ease of Use of 1:1 (PEOU 1:1) and perceived usefulness of 1:1 (PU 1:1) were calculated using two sets of survey items adapted from Davis et al. (1989). On the survey, participants were presented with the statement, "Please indicate your level of agreement with each of the following regarding your 1:1 computing experiences" alongside a 5-point Likert scale with endpoints "extremely likely (5)" to "extremely unlikely (1)." For PEOU 1:1, the items included : (a) learning to operate 1:1 computing would be easy for me, (b) I find it easy to get 1:1 computing devices to do what I want it to do, (c) it was easy for me to become skillful at using 1:1 computing, and (d) I find 1:1 computing easy to use. The items that were combined to create PU 1:1 were: (a) using 1:1 computing in my job increases my productivity, (b) using 1:1 computing enhances my effectiveness on the job, (c) using 1:1 computing makes it easier to do my job, and (d) I find 1:1 computing useful in my job. Both PEOU 1:1 and PU 1:1 were calculated by estimating their sums from the mean of the survey items used to compute them. All summed variables were set at the *X-1* criteria for inclusion in the calculation. Cronbach's alphas were calculated to provide an overall measure of reliability for each set of items. Descriptive statistics and Cronbach's alphas for teachers reported PEOU 1:1 and PU 1:1 are presented in Table 3.

Table 3. *Descriptive Statistics for Teachers' Reported PEOU 1:1 and PU 1:1*

Variable	<i>n</i>	<i>Min</i>	<i>Max</i>	<i>M</i>	<i>SD</i>	Cronbach's <i>a</i>
PEOU 1:1	205	1.00	4.50	1.87	0.78	.94
PU 1:1	207	1.00	4.50	1.71	0.73	.95

The Cronbach's alphas were greater than 0.90, indicating that the constructs PEOU 1:1 and PU 1:1 had strong internal consistency and reliability.

TPACK. Teachers' reported TPACK was measured using five items adapted from Schmidt et al. (2009). Though the researchers originally used eight items to measure TPACK, only five were used in the current study to streamline the survey. On the survey, teachers were asked to indicate their level of agreement with the following statements: (a) I can use strategies that combine content, technologies, and teaching approaches that I learned about in my coursework in my classroom, (b) I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn, (c) I can use strategies that combine content, technologies, and teaching approaches that I learned about in my coursework in my classroom, (d) I can provide leadership in helping others to coordinate the use of the content, technologies, and teaching approaches at my school and/or district, and (e) I can choose technologies that enhance the content for a lesson. Each statement was followed by a 5-point Likert scale with endpoints "strongly agree (5)" to "strongly disagree (1)." The resultant variable TPACK was calculated by estimating the sum from the mean of these survey items used while adhering to the *X-1* criteria for inclusion to compute them. All summed variables were set at the *X-1* criteria for inclusion in the calculation. Table 4 shows the Cronbach's alpha for TPACK was greater than 0.90, indicating that the scales used to construct the variable had strong internal consistency and reliability.

Table 4. *Descriptive Statistics for TPACK*

Variable	<i>n</i>	<i>Min</i>	<i>Max</i>	<i>M</i>	<i>SD</i>	Cronbach's <i>a</i>
TPACK	211	1.00	4.40	1.90	0.67	.90

QUANTITATIVE DATA ANALYSIS

The researchers entered the quantitative data into SPSS® software for analysis. Items that were part of a construct were summed to obtain a single score. Descriptive statistics for teacher demographic and background variables were reported to portray the study's

participants. The results of the survey were summarized by reporting descriptive statistics, including means and frequencies. Cronbach's alphas were calculated to provide a measure of reliability for variables constructed from multiple items.

Linear regression was used to address research question 1, which was concerned with the degree to which perceived ease of Use of 1:1 (PEOU 1:1) and perceived usefulness of 1:1 (PU 1:1) could predict instruction across the subject areas. Davis (1989) posited that external variables relevant to a specific workplace situation might influence perceived usefulness (PU) and perceived ease of use (PEOU). Moreover, studies on classroom technology integration have shown that teachers possess varying levels of TPACK (Jang & Tsai, 2012; Jen et al., 2016). Research has also demonstrated that teachers' self-reported TPACK was a moderator of the relationship between PEOU and PU of the instructional usage of interactive whiteboard technology (Powers, 2018). Therefore, in the current study, moderator analyses were conducted to examine research questions 2 and 3 to explore whether TPACK may serve as a moderator between PU and PEOU and teachers' instructional usage of 1:1 across the subject areas. Individualized instruction in each subject area (mathematics, science, English language arts, and social studies) served as the criterion variable in the first series of regressions. Then the regressions were repeated with whole-class instruction in each subject area functioning as the criterion variable. The predictor variables included in the linear regressions were PEOU 1:1. The regressions were repeated with PU 1:1 as the predictor. For the moderator analyses, each regression included either PEOU 1:1 or PU 1:1 and an interaction term (i.e., PEOU 1:1 * TPACK or PU 1:1 * TPACK). The level of significance for each of the models was set at an alpha of .05. The variables included in the moderator analyses were means-centered.

RESEARCH QUESTION ONE

Research question 1 examined the degree to which teachers' perceived ease of use of 1:1 and perceived usefulness of 1:1 predict their reported instructional usage of 1:1 for instruction across subjects.

As shown in Table 5, the results indicated that Beta values for predictor variable PEOU 1:1 was significant ($p \leq .05$) and positively related to individualized instruction in all subjects.

Table 5. *Regression Coefficients for Predictor Variable Teachers' PEOU 1:1 and Criterion Variables Frequency of Use of 1:1 for Individualized Instruction Across Subject Areas*

Criterion Variable	Predictor	Beta	<i>t</i>
Mathematics	PEOU 1:1	.322 *	4.37
Science	PEOU 1:1	.359 *	4.81
English language arts	PEOU 1:1	.463 *	6.82
Social studies	PEOU 1:1	.370 *	4.54

Note: * $p < .001$, Mathematics: $R^2 = 0.098$ ($F(1,165) = 19.051$, $p < .001$), Science - $R^2 = 0.123$ ($F(1, 156) = 23.098$, $p < .001$), English language arts - $R^2 = 0.210$ ($F(1, 170) = 46.486$, $p < .001$), and Social studies - $R^2 = 0.130$ ($F(1,130) = 20.636$, $p < .001$).

These results indicated that the variability in the use of 1:1 for individualized instruction explained by the models ranged from 9.8% to 21.0%.

Regarding the relationship between PU 1:1 and the criterion variable teachers' frequency of use of 1:1 for individualized instruction across the subject areas, the following results were found and are presented in Table 6.

Table 6. *Regression Coefficients for Predictor Variable Teachers' PU 1:1 and Criterion Variables Frequency of Use of 1:1 for Individualized Instruction Across Subject Areas*

Criterion Variable	Predictor	Beta	t
Mathematics	PU 1:1	.412 *	5.841
Science	PU 1:1	.354 *	4.742
English language arts	PU 1:1	.542 *	8.427
Social studies	PU 1:1	.315 *	3.783

Note: * $p < .001$, Mathematics: $R^2 = 0.165$ ($F(1, 167) = 34.121, p < .001$), Science $R^2 = 0.120$ ($F(1, 157) = 22.486, p < .001$), English language arts - $R^2 = 0.289$, ($F(1, 171) = 71.014, p < .001$), and Social studies - $R^2 = 0.092$ ($F(1, 130) = 14.309, p < .001$).

These results indicated that the variability in the use of 1:1 for individualized instruction explained by the models ranged from 9.2% to 28.9%.

Regarding the relationship between PEOU 1:1 and the criterion variable teachers' frequency of use of 1:1 for whole-class instruction across the subject areas, the following results were found and are presented in Table 7.

Table 7. *Regression Coefficients for Predictor Variable Teachers' PEOU 1:1 and Criterion Variables Frequency of Use of 1:1 for Whole-Class Instruction Across Subject Areas*

Criterion Variable	Predictor	Beta	t
Mathematics	PEOU 1:1	.356*	4.831
Science	PEOU 1:1	.293*	3.826
English language arts	PEOU 1:1	.436*	6.266
Social studies	PEOU 1:1	.305*	3.640

Note: * $p < .001$, Mathematics: $p \leq .05$. $N = 162, R^2 = 0.121, F(1, 161) = 23.342, p < .001$, Science: $p \leq .05$. $N = 157, R^2 = 0.080, F(1, 156) = 14.636, p < .001$, English language arts: $p \leq .05$. $N = 168, R^2 = 0.165, F(1, 167) = 39.257, p < .001$, and Social studies: $p \leq .05$. $N = 130, R^2 = 0.086, F(1, 129) = 13.248, p < .001$.

These results indicated that the variability in the use of 1:1 for whole-class instruction explained by the models ranged from 8.0% to 16.5%.

Regarding the relationship between PU 1:1 and the criterion variable teachers' frequency of use of 1:1 for whole-class instruction across the subject areas, the following results were found and are presented in Table 8.

Table 8. *Regression Coefficients for Predictor Variable Teachers' PU 1:1 and Criterion Variables frequency of Use of 1:1 for Whole-Class Instruction Across Subject Areas*

Criterion Variable	Predictor	Beta	t
Mathematics	PU 1:1	.427*	6.024
Science	PU 1:1	.365*	4.905
English language arts	PU 1:1	.455*	6.617
Social studies	PU 1:1	.269*	3.174

Note: * $p < .001$, Mathematics: $p \leq .05$. $N = 164, R^2 = 0.117, F(1, 163) = 36.286, p < .001$, Science: $p \leq .05$. $N = 158, R^2 = 0.127, F(1, 157) = 24.056, p < .001$, English language arts: $p \leq .05$. $N = 184, R^2 = 0.202, F(1, 183) = 43.787, p < .001$, and Social studies: $p \leq .05$. $N = 130, R^2 = 0.165, F(1, 129) = 10.072, p < .001$.

These results indicated that the variability in the use of 1:1 for individualized instruction explained by the models ranged from 11.7% to 20.2%.

RESEARCH QUESTION TWO

Research question 2 focused on whether the teachers' reported TPACK moderated the relationship between PEOU 1:1 and the use of 1:1 for instruction across subjects.

These moderator analyses for PEOU 1:1 and whole-class instruction in each subject are presented in Table 9.

Table 9. *Moderator Analyses of TPACK on the Relationship between PEOU 1:1 and use of 1:1 for Whole-Class Instruction Across Subject Areas*

Criterion Variable	Predictor	Beta	se	t	p
Mathematics	PEOU 1:1 * TPACK	0.130	0.093	1.71	0.130
Science	PEOU 1:1 * TPACK	0.159	0.098	2.041	0.043*
English language arts	PEOU 1:1 * TPACK	0.1338	0.654	0.514	0.514
Social studies	PEOU 1:1 * TPACK	0.123	0.127	1.62	0.109

Note: * Mathematics: $p \leq .05$. $N = 162$. $R^2 = .186$, $F(3, 159) = 12.1$, $p < .001$, Science: $p \leq .05$. $N = 157$. $R^2 = .176$, $F(3, 154) = 11.0$, $p < .001$, English language arts: $p \leq .05$. $N = 168$. $R^2 = .273$, $F(3, 165) = 18.1$, $p < .001$, Social studies: $p \leq .05$. $N = 130$. $R^2 = .247$, $F(3, 127) = 13.9$, $p < .001$.

The results indicated that TPACK was a significant moderator of the relationship between PEOU 1:1 and the use of 1:1 for whole-class instruction in the subject of science. The coefficients were positive, indicating that increasing the moderator would strengthen the effect of PEOU 1:1 on the use of 1:1 for whole-class science instruction.

The moderator analysis that examined the influence of TPACK on the relationship between PEOU 1:1 and individualized instruction across the subject areas yielded two significant moderators. The results are presented in Table 10.

Table 10. *Moderator Analyses of TPACK on the Relationship between PEOU 1:1 and use of 1:1 for Individualized Instruction Across Subject Areas*

Criterion Variable	Predictor	Beta	se	t	p
Mathematics	PEOU 1:1 * TPACK	0.152	0.081	2.03	0.044*
Science	PEOU 1:1 * TPACK	0.162	0.085	2.23	0.027*
English language arts	PEOU 1:1 * TPACK	0.034	0.082	0.50	0.621
Social studies	PEOU 1:1 * TPACK	0.128	0.098	1.70	0.092

Note: * Mathematics: $p \leq .05$. $N = 166$. $R^2 = .183$, $F(3, 163) = 12.2$, $p < .001$, Science: $p \leq .05$. $N = 171$. $R^2 = .273$, $F(3, 168) = 21.1$, $p < .001$, English language arts: $p \leq .05$. $N = 171$. $R^2 = .273$, $F(3, 168) = 21.1$, $p < .001$, Social Studies: $p \leq .05$. $N = 131$. $R^2 = .316$, $F(3, 128) = 19.7$, $p < .001$.

The results indicated that TPACK was a significant moderator of the relationship between PEOU 1:1 and 1:1 for individualized instruction in mathematics and science subjects. The coefficients were positive, indicating that increasing the moderator would strengthen the relationships between PEOU 1:1 and individualized mathematics and science instruction.

RESEARCH QUESTION THREE

Research question 3 focused on whether the teachers' reported TPACK moderated the relationship between PU 1:1 and the use of 1:1 for instruction across subjects.

The results of these moderator analyses for PU 1:1 and whole-class instruction in each subject are presented in Table 11.

Table 11. Moderator Analyses of TPACK on the Relationship between PU 1:1 and use of 1:1 for Whole-Class Instruction Across Subject Areas

Criterion Variable	Predictor	Beta	se	t	p
Mathematics	PU 1:1 * TPACK	0.136	0.101	1.86	0.065
Science	PU 1:1 * TPACK	0.177	0.114	2.35	0.020*
English language arts	PU 1:1 * TPACK	0.044	0.134	0.65	0.514
Social studies	PU 1:1 * TPACK	0.130	0.160	1.67	0.097

Note: * Mathematics: $p \leq .05$. $N = 163$. $R^2 = .232$, $F(3, 160) = 16.1$, $p < .001$, Science: $p \leq .05$. $N = 158$. $R^2 = .208$, $F(3, 155) = 13.6$, $p < .001$, English language arts: $p \leq .05$. $N = 168$. $R^2 = .273$, $F(3, 165) = 20.6$, $p < .001$, Social studies: $p \leq .05$. $N = 130$. $R^2 = .249$, $F(3, 127) = 14.0$, $p < .001$.

The results indicated that TPACK was a significant moderator of the relationship between PU 1:1 and the use of 1:1 for whole-class instruction in the subject of science. The coefficients were positive, indicating that increasing the moderator would strengthen the effect of PEOU 1:1 on the use of 1:1 for whole-class science instruction.

The moderator analysis that examined the influence of TPACK on the relationship between PU 1:1 and individualized instruction across the subject areas yielded one significant moderator. The results are presented in Table 12.

Table 12. Moderator Analyses of TPACK on the Relationship between PU 1:1 and use of 1:1 for Individualized Instruction Across Subject Areas

Criterion Variable	Predictor	Beta	se	t	p
Mathematics	PU 1:1 * TPACK	0.149	0.095	2.05	0.042*
Science	PU 1:1 * TPACK	0.131	0.102	1.82	0.071
English language arts	PU 1:1 * TPACK	-0.018	0.106	-0.29	0.776
Social studies	PU 1:1 * TPACK	0.116	0.133	1.55	0.124

Note: * Mathematics: $p \leq .05$. $N = 167$. $R^2 = .223$, $F(3, 164) = 15.7$, $p < .001$, Science: $p \leq .05$. $N = 158$. $R^2 = .281$, $F(3, 155) = 20.2$, $p < .001$, English language arts: $p \leq .05$. $N = 171$. $R^2 = .339$, $F(3, 168) = 28.7$, $p < .001$, Social Studies: $p \leq .05$. $N = 131$. $R^2 = .313$, $F(3, 127) = 19.5$, $p < .001$.

The results indicated that TPACK was a significant moderator of the relationship between PU 1:1 and the use of 1:1 for individualized instruction in the subject of mathematics. The coefficient was positive, indicating that increasing the moderator would strengthen the relationship between PU 1:1 and individualized mathematics instruction.

DISCUSSION

Regarding our first research question, "To what degree do teachers' perceived ease of use of 1:1 and perceived usefulness of 1:1 predict their reported use of 1:1 for instruction in mathematics, science, English language arts, and social studies?" The results of the regression analyses showed that the variables teachers' PU 1:1 and PEOU 1:1 were significant predictors for the use of 1:1 for instruction in all subjects in both whole and individualized forms. These findings supported Davis's (1989) theory that a users' perceived usefulness and perceived ease of use of technology in the workplace can influence its adoption. This finding was illustrated by one of the teachers in the open-ended survey responses. One teacher wrote, "The options for lessons and activities are so vast and easily accessible for teachers and students. In a world where technology drives the workplace, it is imperative students learn how to utilize computers and do so effectively."

This teachers' comment serves as an example of how the teacher found teaching lessons with 1:1 was easy to do and useful. Students gain experience in technological tools to prepare for their futures.

The second research question in this study was, "Is the relationship between teachers' perceived ease of use of 1:1 and their reported use of 1:1 for each subject moderated by teachers' reported TPACK?" This study's findings have established that TPACK was a significant moderator of the relationships between PEOU of 1:1 in both whole-class and individualized science instruction, and individualized mathematics instruction. The third research question in this study was, "Is the relationship between teachers' perceived usefulness of 1:1 and their reported use of 1:1 for each subject moderated by their reported TPACK?" For this question, the findings demonstrated that TPACK was a significant moderator of the relationships between PU 1:1 and the use of 1:1 for whole-class science instruction and individualized mathematics instruction. The direction of the Betas of the interaction term for each of the significant moderator analyses was positive, indicating the higher teachers' perceptions were regarding their TPACK, the greater the influence of PEOU 1:1 or PU 1:1 on teachers' use of 1:1 for these forms of mathematics and science instruction. These findings supported the notion that TPACK may serve as an external variable that can influence the relationship between a user's perceived ease of use, usefulness, and actual use of technology in the workplace (Davis et al., 1989). Figure 2 shows a visual representation of the study's findings.

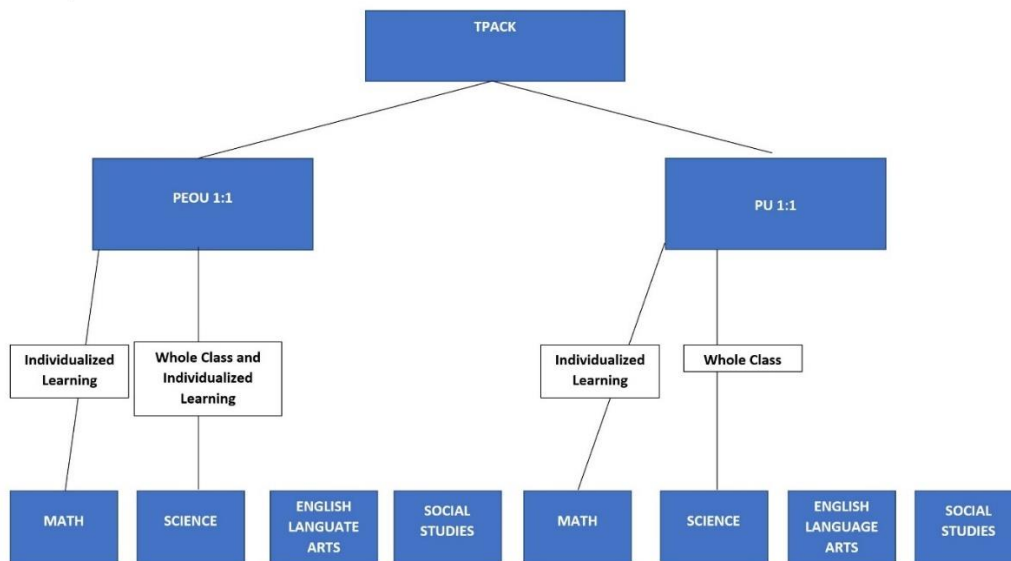


Figure 2. Visual representation of the study's findings

It is interesting to note that in this study, TPACK was not a significant moderator of any of the relationships between PEOU or PU and instruction involving 1:1 in the subjects of English language arts or social studies. However, as demonstrated by the regression analyses in research question 1, PEOU 1:1 and PU 1:1 did play a strong role in predicting all forms of instruction we examined in all subject areas. One teacher in the study described the use of 1:1 across subjects as follows, "I use it for all subjects. Students use their laptops for research and for creating products for their projects. They also use them to collaborate on assignments and to communicate on Skype." The lack of a significant moderator regression for TPACK in these subjects simply indicated that TPACK did not play a role in altering those relationships.

When examining the differences between PEOU and PU across subject areas, it is essential to look more closely at the availability of software applications and the emphasis placed on the subject. Science and mathematics teachers may have access to more interactive computer simulations that are pedagogically engaging and not readily available in other subject areas. STEM education, including coding, is frequently emphasized in curriculum. The role of ELA teachers has become more complicated, encompassing new literacies on top of the fundamental skills of reading and vocabulary. These factors could affect TPACK in both PU and PEOU. Finally, research suggests that state policy mandates, grade-specific curricular organization, and teacher disposition have a substantial impact on the prioritization of social studies in elementary schools in the United States (Fitchett et al., 2014). Currently, the subject of social studies is not required to be tested in elementary grades (Florida Department of Education, 2019).

LIMITATIONS

The population of this study included only elementary teachers from one school district. Therefore, results can only be generalized to this subset of teachers. The participants were predominantly female, although this is not unusual to find in the elementary education field. Another limitation of this study is that data included in the analyses were measured using a self-report survey, reflecting each item's teachers' perceptions.

CONCLUSIONS AND FUTURE DIRECTIONS

The results of this study demonstrated that elementary school teachers PEOU 1:1 and PU 1:1 played a strong role in predicting all the forms of instruction we examined across subject areas. Further, this research indicated that TPACK moderated and strengthened the relationship between PEOU of 1:1 and PU 1:1 and several forms of mathematics and science instruction. These findings suggest that school leaders aiming to strengthen teachers' adoption of 1:1 in the subject areas of mathematics and science can do so by focusing on strategies that can enhance teachers' TPACK. Future directions in research might show why this difference appears between subject areas. TPACK in elementary teachers may be affected by larger issues in the educational system, such as the emphasis placed on curriculum areas of mathematics and science or the technology applications available.

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