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DEVELOPMENT ARTICLE

Utility and usability as factors influencing teacher decisions about software integration

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Abstract Given the importance of teacher in the implementation of computer technology in classrooms, the technology acceptance model and TPACK model were used to better understand the decision-making process teachers use in determining how, when, and where computer software is used in mathematics classrooms. Thirty-four (34) teachers implementing Geometer's Sketchpad and Fathom in algebra and geometry classrooms were observed and interviewed using the above models. The factors of perceived ease of use and perceived usefulness, and their contributing sub-factors, were used to elaborate on how teachers differed in their perceptions and actual use of these two software tools in different instructional contexts. The two primary themes that emerged were teachers' comfort level with using the software tools and how this interacted with their perceived ease of use, and their understanding of the software's capabilities and alignment with their curricular and teaching goals. This alignment became the over-riding factor driving perceived usefulness. Secondary factors influencing perceived usefulness included alignment with preferred pedagogical strategies and support from fellow teachers. This last factor probably also crossed over to perceptions of ease of use.

Keywords Technology acceptance model (TAM) · TPACK · Mathematics · Software · Curriculum · Pedagogy

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Introduction

A key trend in K-12 classrooms over the last 10 years has been the increased use of computing devices as part of everyday instructional activity, but with mixed effects on instruction. At the high school level in particular, this has included instructional models based on one computing device for every student (i.e., 1:1 models) (Drayton et al. 2010). In a meta-analysis of 1:1 initiatives across six states, Argueta et al. (2011) concluded that teacher decisions around the implementation of this technology was central to its impact on learning. While intensive and constructive levels of implementation were associated with increased student engagement and motivation to learn, low levels of implementation led to student distraction and indifference to effective laptop use.

While the potential educational benefits of effective integration of technology such as laptops into classrooms seems apparent, researchers have continued to document the challenges teachers face achieving robust integration in contexts such as mathematics classrooms (Norton et al. 2000). While teachers will often make use of standard office productivity tools (i.e., word processors or spreadsheets), more specialized software with which they are less familiar are less likely to be readily integrated (Handal et al. 2013). In addition, when new software tools are rolled out across a school or district, their integration and use is typically uneven across teachers (Cavanagh and Mitchelmore 2011).

In a recent mathematics education research study,Hegedus et al. (2016) found that teachers' utilization of technology impacted students' learning and achievement. However, the simple availability of technology in classrooms and its affordances may not assist students in learning; "rather, it is teachers' decisions about how, when, and where to use technology that determine whether its use will enhance or hinder students' understandings of mathematics" (Hollebrands and Zbiek 2004, p. 259). Enhanced use of technology in mathematics classroom is most often associated with teachers' instructional practice (Hegedus et al. 2016) and technological pedagogical content knowledge (Tabach 2011).

Given that the trends towards increased computerization of the classroom are likely to continue, it is important to better understand what the barriers are to effective utilization. As noted, there is often an interaction between the type of software, the instructional domain, and utilization in the classroom (Handal et al. 2013; Stols and Kriek 2011). While top-down assessment of a software tool's feature set against the curricular goals may point to great potential as a learning tool, lack of effective utilization (or any utilization at all) will blunt its potential to support student learning. Worse, software and hardware, in the classroom but not used, may in fact become a negative contributor by acting as a distracting element.

Given the importance of the teacher in the implementation of computer technology in classrooms, this article builds off existing research by developing a better understanding of the decision-making process teachers use in determining how, when, and where computer software is used in mathematics classrooms. More specifically, given a ubiquitous computing environment where computers are always available to mathematics teachers and students, what drives decisions about which mathematics software tools are utilized and in what ways?

Theoretical framework

The introduction of new computer-based tools, such as a new software package, in the classroom triggers a set of decisions to be made by a teacher. Teachers need to make decisions about the use of this software package within the instructional setting based on a number of factors (Goos et al. 2010). These include macro-scale factors around organizational support through tech support services and professional development (Forgasz 2006). However, teacher beliefs concerning the alignment of software to curricular and instructional goals (Kim et al. 2013), along with more micro-scale factors such as one's comfort with learning how to use a new software package in the context of instruction are also critical (Polly 2011). Within the discipline of mathematics, researchers (e.g., Doerr and Zangor 2000) have found close alignment between teachers' beliefs about learning mathematics, as identified through their pedagogical preferences, and their level of incorporating technology in mathematics curriculum. Two theoretical models, Technological pedagogical content knowledge (TPACK) and technology acceptance model (TAM), are particularly useful in thinking about a teacher's decision-making process.

TPACK

The TPACK model (Koehler and Mishra 2009; Mishra and Koehler 2006) helps to frame the decision-making process that a teacher goes through when integrating technology in the mathematics classroom. TPACK arose as a structured way of thinking about how technology reshapes pedagogical content knowledge that teachers utilize to strategically guide instruction and learning in the classroom (Koehler and Mishra 2009). This framework recognizes the important role technology plays in mediating channels of information between students, and between students and teachers. Appropriately, researchers have applied this model to a range of educational technology integration challenges, including 1:1 classrooms (cf., Spires et al. 2012).

TPACK is often thought of as an outgrowth of Shulman's PCK model (Shulman 1986, 1987). Many researchers have used the PCK model as a way of thinking about knowledge of pedagogy (PK), apart from the disciplinary content knowledge (CK), that a teacher needs in order to effectively support learning in the classroom (Segall 2004). TPACK, as an outgrowth of PCK, was an appropriate response to ever-increasing sophistication of technology being introduced to classrooms and the recognition that instructional technology needed to be considered by researchers, conceptually and theoretically, as to its role in shaping teaching and learning (Angeli and Valanides 2009). Mishra Mishra and Koehler (2006) point out that technology and content are reciprocally related, with TCK (Technological Content Knowledge) helping explain the ways a teacher understands the capabilities of a particular technology and how to use that technology to teach a specific content (Harris and Hofer 2011). On the other hand, TPK (Technological Pedagogical Knowledge) recognizes that both teachers and technology can be pedagogical agents supporting learning in the classroom (Ng 2012), with the teacher needing to make decisions as to how they will articulate with the technology. TPACK also acknowledges that effective pedagogical uses of technology are deeply influenced by the content domains in which they are situated (Lee and Hollebrands 2011; Mishra and Koehler 2006).

In addition to being a powerful tool for examining instruction as it unfolds in the classroom, the TPACK framework provides an analytical lens with which to look at the instructional decisions that teachers make leading up to instruction (Graham et al. 2012). A study by Harris and Hofer (2011) using the TPACK framework found that teachers often weighed the affordances of new technologies against their instructional goals. That is, they specifically looked for the 'fit' of the technology against the content and pedagogical strategies they were going to employ. Harris et al. (2009) determined that it was important for technology integration to be consistent with the planning process of teachers. Thus, teachers would first determine the curriculum to be taught, then select activities to support student learning and last identify technology to support the chosen activities. These findings were consistent with Manfra and Hammond's (2008) case study of two social studies teachers which also found that pedagogy, not technology, drove teachers' decisions on lesson plans. It is interesting that in many of these studies, especially those with new or pre-service teachers, the rationales expressed seem to be more closely related to general pedagogical practices than to content-specific pedagogical practices (Graham et al. 2012).

This review of the TPACK model points to two strong themes that emerge from these research studies: investigations of what unfolds within the classroom and studies on the decision-making process which teachers go through up front in deciding which technology tools they are going to use. While these two thematic elements often play out in a dynamic cyclical fashion in instructional settings, each is worthy of study in their own right. A complementary model, the TAM, provides a basis for a focused analysis of these two elements.

TAM

Another model, widely used to understand adoption of technological tools in the workplace, is the Technology Acceptance Model (TAM; Davis, 1989; Venkatesh and Bala 2008). Though not as widely used to study integration into instructional settings, the TAM provides a rich framework for understanding the decision-making process of the teacher. The TAM was initially developed by Davis (1989) and further refined over the next decade by Davis and others. Ongoing work by Venkatesh and colleagues has ultimately led to the TAM3 model (Venkatesh and Bala 2008). The TAM models have garnered extensive empirical support (Behrend et al. 2011; Bourgonjon et al. 2010; Stols and Kriek 2011; Sun and Zhang 2006), and provide a robust framework that is well-aligned with TPACK-based research on technology decision-making by teachers. The TAM model is especially complimentary to TPACK in that it provides a focused, robust exposition of the determinants of perceived usefulness and ease of use, allowing for a detailed and structured investigation of factors underlying the technology integration decision-making process. These factors associated with the TAM have typically been studied quantitatively through self-report survey instruments, but are equally well-suited for interviewing and similar qualitative data collection techniques.

The TAM posits that individuals' behavioral intention to use information technology is determined by two beliefs: perceived usefulness and perceived ease of use (Davis 1989). *Perceived usefulness* is defined as the extent to which a person believes that using a technology will enhance their job performance while *perceived ease of use* is defined as the degree to which a person believes that using a technology for a particular task will be free of effort (Venkatesh and Bala 2008). In the context of our study, the "job" is being a classroom teacher with the task of using software tools to further student learning. Software may be used directly by the teacher for demonstration purposes or used by students with teacher guidance. In both cases, we are interested in the teacher's perceptions of both the ease of use of the software and its usefulness for furthering learning.

For perceived ease of use, individual differences are important determinants of this construct. Probably the most relevant of the identified factors is computer technology self-efficacy, the degree to which an individual believes that they have the ability to perform a specific task or job using a computer or related technology (Compeau and Higgins 1995; Wiebe et al. 2003). It is important to note that this construct is influenced both by general feelings of self-efficacy around computers and computer technology and specific software tools.

Perceived usefulness is both indirectly influenced by perceived ease of use (i.e., if the software is not easy to use, it probably won't be very useful) and by a number of other relevant factors. These include subjective norm, result demonstrability, and task relevance (Venkatesh and Davis 2000). Subjective norm encompasses a number of elements, including the degree to which one believes they have the support of their organization (e.g., principal) and peers (e.g., fellow teachers). Results demonstrability is the degree to which one can tangibly see the benefits of using the technology tool and how easy it is to demonstrate these results to others (Moore and Benbasat 1991). Perhaps the most important factor is perceived task relevance, which not only appears in the TAM models but many other allied models of technology integration (e.g., Venkatesh et al. 2003; Nistor et al. 2013).

The TAM model was conceived for use in task-driven work environments not unlike schools, so it is appropriate that an individual teachers' perception of the relevance of a technology tool to their specific task goals is central to their decision to utilize it. These psychological factors influencing perceived usefulness and ease of use are often difficult to elicit as direct self-report data from users in a specific work context. Because of this, more direct, contextualized probes are used with users, asking them about facilitating conditions in their workplace, the system characteristics, social influences driving their decision-making, and individual differences such as their perceived competence with the technology. Figure 1 represents the core components of the current TAM3 model and the factors specifically explored in this research. The four factors on the left side of the model can be considered the primary determinants driving beliefs of perceived usefulness and perceived ease of use. The next column of factors can be considered derived secondary factors more specifically related to each core belief. Based on this model the two beliefs, perceived usefulness and perceived ease of use, drive the latent factor, behavioral intention, which in turn results in the observed use behavior. The resulting use (i.e., experience) will feed back into potential reshaping of the primary determinants.

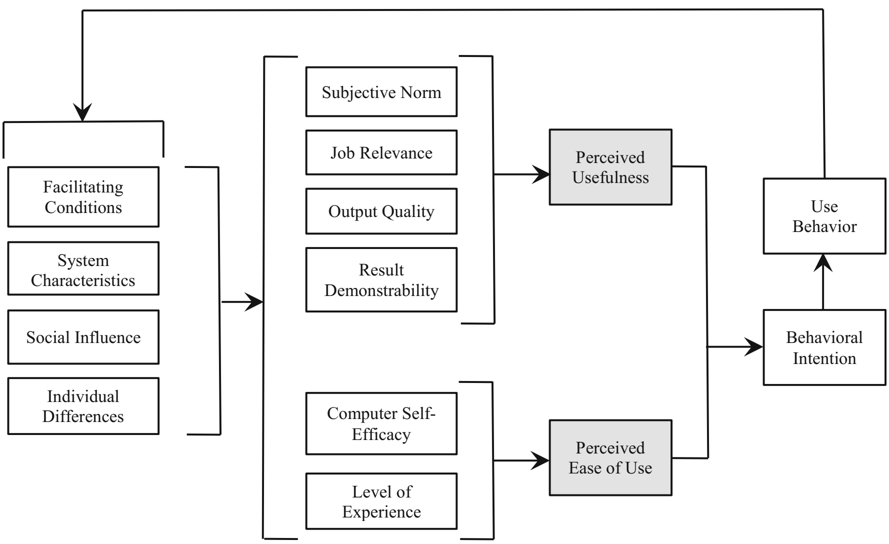

Fig. 1 TAM3 model adapted for this study (adapted from Venkatesh and Bala 2008)

The utilization of the TAM model for research in business settings is well-aligned with parallel work done in educational settings. Related to computer self-efficacy and perceived ease of use, researchers (e.g., Forgasz 2006; Swan and Dixon 2006; Thomas 2006) have found that teachers' confidence with technology was identified as one of the most common inhibiting factors of using technology in mathematics curricula. Similarly, Handal et al. (2013) classified the factors that influence teachers' use of technology as *instructional*, *curricular*, and *organizational*. All three of these factors help to contextualize a more general model of perceived usefulness into instructional settings where teachers are making decisions about technology use in classrooms. *Instructional* factors include teachers' perceptions of their ability to support students' use of the technology. *Curricular* factors include teachers' attempts to align technology tools with curricula, associated support materials and the time allotted to teach a particular topic. Finally, *organizational* factors included technical and logistic issues including perceptions of the level of support they would receive from staff in the school.

Specific to the mathematics classroom, Stols and Kriek (2011) used the TAM model to look at the introduction of dynamic geometry software (The Geometer's Sketchpad and GeoGebra) to South African mathematics teachers during a three-week workshop, and collected data using a questionnaire. Using the TAM model constructs, the researchers investigated both the perceived ease of use and perceived usefulness (by the teachers) of the software tools. Contrary to some previous research (cf., Swan and Dixon 2006), results indicated that teachers' confidence with technology (perceived ease of use) was not a significant factor on teachers' planned use. However, perceived usefulness, which was associated with enhancing teaching performance through the use of technology, was a significant factor towards its planned use. The researchers also found that teachers' perceived compatibility of the technology with their existing pedagogical beliefs on teaching and alignment with curricular goals were important. On the other hand, teachers were less concerned about expectations from colleagues. Although the researchers could not find any significant effect on teachers' perceived ease of use of geometry software, the researcher found a significant relationship between teachers' general technology proficiency and their intention of using technology.

In summary, TPACK model provides an overarching framework for technology integration in classrooms by teachers. As such, it provides the implicit framing of the entire TAM model in Fig. 1, explicating the initial driver for the teacher's consideration of curricular integration of software tools into their classrooms. The TAM model and related research, then, allows us to carefully and systematically examine a teacher's decision-making process of integrating software-based technology tools in the classroom. Prior research clearly indicates that this decision-making, while it includes general beliefs and characteristics of teachers, is highly contextualized in specific teaching and learning goals. Therefore, it is expected that the teachers' perceptions of ease of use and usefulness will be dependent on both the software tool being deployed and the specific curricular context in which the software is being utilized. TPACK frames the decision-making process in terms of instructional goal-directed decisions as to how to best utilize these software tools. As with many of the cited studies, this research is situated in high school mathematics classrooms, namely a first year algebra course and a geometry course. The research questions being pursued, with regards to teachers' integration of student learning software tools in algebra and geometry classrooms are:

(1) How does the perceived ease of use and usefulness differ across software tools and curricular contexts?
(2) What specific factors seem to drive perceptions of ease of use and usefulness?

Methods

This research was conducted as a qualitative case-based study (Stake 1995). The unit of analysis of the current study was teachers and their classrooms, with data a priori grouped and analyzed based on a combination of curricula and software tools being deployed. Data collection included both interviews with teachers and observations of their classroom instruction, guided by both the TPACK and TAM3 frameworks. Interview data contained both narrative and numeric responses to question prompts. These numeric responses were described using descriptive statistics and triangulated with other data sources. The goal was to document the differences in perceived usefulness and usability of software tools based on the curricular context in which they were being used. This research was conducted over 3 years.

In this case study research (Stake 1995), we adopted a constant comparative analysis outside of grounded theory (Fram 2013). Stake (1995) underlines that researchers should be an interpreter in case studies to understand and explain a phenomena in natural settings providing *thick descriptions* (Lincoln and Guba 1985). Our research study utilizes constant comparative analysis *for thickness* (see O'Connor et al. 2008), in particular, giving direct excerpts from the interviews to support our findings and a detailed description about research context. Our constant comparative analysis began after we collected data over a 3-year period. Because of the number of teachers involved in this study, thickness will be developed around emergent themes arising across case groupings of teachers, rather than any one individual teacher.

Fram (2013) developed a novel way to use constant comparative analysis outside of grounded theory in which theoretical frameworks guide researchers. Fram (2013) suggested using constant comparative analysis to maintain the *emic* perspective where researchers are in an inside position (e.g., taking an active role in data collection), and a theoretical framework to maintain *etic* perspective where researchers are in an outside position examining the data sets in line with the framework. Correspondingly, qualitative researchers may make intentional attempts to make connections between emic and etic perspectives. Etic view is associated with quantitative approaches as researcher takes an outside position, and emic view is associated with qualitative data inasmuch as meaning making and theoretical models come from the data (Nastasi and Schensul 2005). However, Fram (2013) views etic perspective as fitting data into an existing framework within a qualitative approach, and makes a transition from emic to etic view. We make a transition from emic to etic views aligning our data with the TAM3 and TPACK models.

Research context

Participants

The thirty-four (34) participant teachers in this study were a subset of a larger population of teachers participating in a study on effective mathematics education professional development in 1–1 laptop classrooms. The set of 34 teachers was selected in order to provide a diverse group in terms of geographical location, gender, years of experience, technology knowledge, and school system. In addition, these teachers provided for the creation of cases that maximized our opportunity to analyze and understand the witnessed behaviors via theory (Stake 1995). The participants' professional experience range from beginning teachers to veterans with over 30 years in the classroom, the mean being 5.9 years of

Table 1 Distribution of participant teachers across years, curricula, and software

Software–PD	Year one (YI)	Year two (YII)	Year three (YIII)
GSP–Geometry	T1–T11	T2, T3, T8, T13, T14, T26, T27	–
GSP–Algebra	–	T3, T8, T9, T12, T15–T25	–
Fathom–Algebra	–	–	T11, T12, T17, T24, T28–T34

teaching. Individual teachers are referred to in the Findings by a number (e.g., T4) and the year in which the interview was conducted (e.g., YII). Table 1 shows the distribution of teachers across years, curricula, and software.

Software

The programs used in this research to address the research questions were: (1) The Geometer's Sketchpad (GSP) and (2) Fathom. They were chosen because they address the emerging curriculum needs of secondary math education. Additionally, the dynamic and interactive nature of the software had the potential to impact the pedagogical strategies of the teacher. GSP allows users to construct shapes and figures, make measurements, and drag objects (Fig. 2). Because the figure maintains the constraints imposed in its creation (e.g., perpendicular lines), students can explore its properties. When the software program is opened, a blank sketch appears. Students can choose "free-hand" tools such as segments, lines and circles. They can also pull down menus to perform constructions (e.g., parallel lines, perpendicular lines) or to execute transformations (e.g., translations, reflections, rotations). The interface is intuitive and user-friendly and students and teachers quickly learn how to use the different tools and menus.

This investigative approach to geometry has been promoted by the National Council of Teachers of Mathematics (National Council of Teachers of Mathematics 2000, 2009, 2014) and is aligned with standards (CCSSI 2012). GSP software was the focus of the first two years of the research project.

In the third and final year of the project, a second software program, Fathom, was introduced. This software was chosen for its potential to support data-driven mathematical and statistical problem-solving, a goal of the new K-12 mathematics standards. Fathom allows students to either use stock data or collect their own, drag attributes to the x- and y-axes to dynamically build graphs, and to click on data in cards, case tables, and graphs to explore linked representations of the data (Fig. 3). When one opens the software program the tools available will be empty unless data have been pasted or entered. Students and teachers must actively build graphs by dragging the attributes they are interested in examining to the x- and y-axes.

It is important to note that both software programs go further than simply presenting information via technology. These software tools were adopted based on their potential for changing the way the mathematical concepts are taught. Because of this, teachers were given intensive ongoing professional development.

Professional development (PD)

The PD received by the teachers was given in two formats: (1) in-person and (2) online. The in-person PD took place during the summer when teachers were able to spend five full days collaborating with experts and peers while working with the software. During this

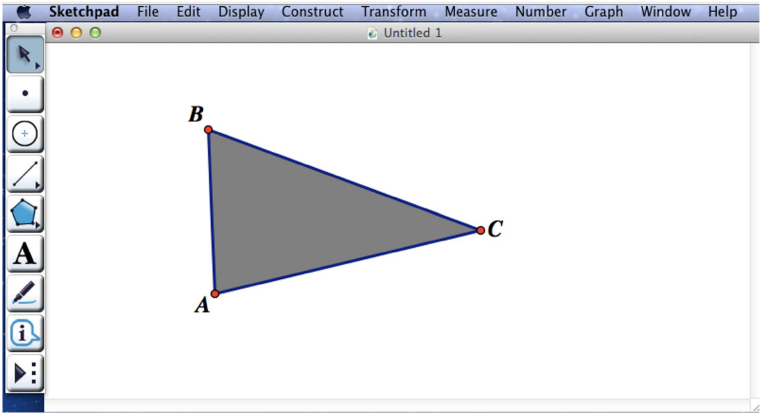

Fig. 2 Interface for Geometer's Sketchpad (GSP)

time, they completed mathematical tasks using the technology, participated in discussions, and planned and presented tasks. In addition to the week-long workshop, the PD continued throughout the school year via an online course and discussion group. The teachers watched videos, completed activities and lesson plans, and communicated with each other on a monthly-basis. The time spent receiving online PD totaled approximately 40 h per teacher each school year.

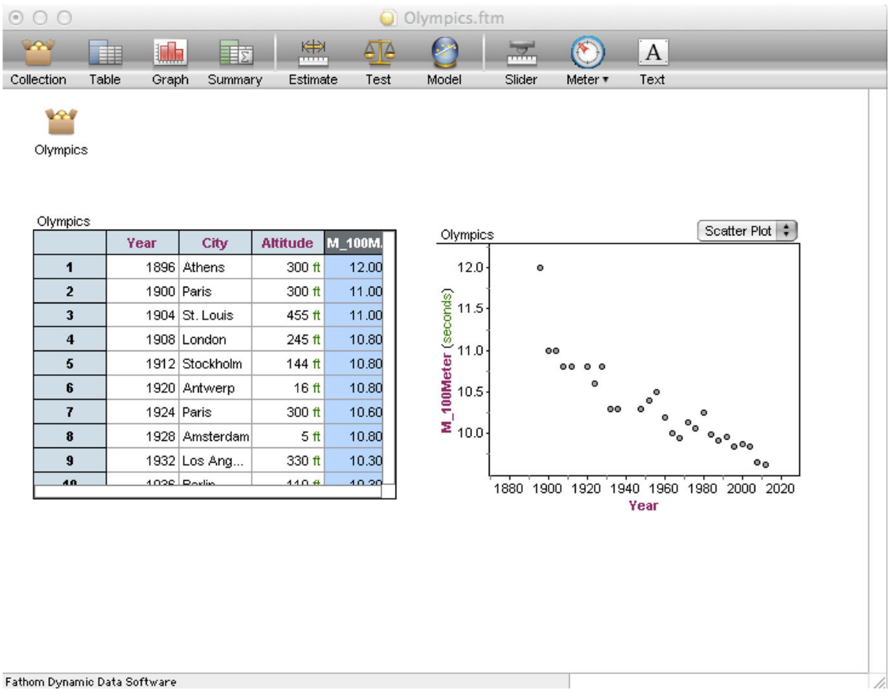

Fig. 3 Interface for Fathom

Procedure

Year one

School systems were selected based on the technological infrastructure in place, namely that they had or were in the process of implementing a 1–1 laptop program school-wide. The first year cohort consisted of Geometry teachers, who attended the in-person PD prior to the start of the school year. Additionally, they participated in monthly online PD opportunities, which allowed them to collaborate with other teachers. The focus of the in-person and online PD was on the use of GSP in geometry classrooms. Over the next school year, the teachers were observed teaching geometry and interviewed.

Year two

Algebra teachers in the participating schools attended an in-person PD during the summer before the start of the school year. Online-PD was also required monthly, as with the first year. It is important to note that those teachers in attendance consisted of the newly recruited Algebra teachers, as well as the returning Geometry teachers. The focus of the in-person and online PD was on the use of GSP in algebra classrooms. Over the next school year, the teachers were observed teaching algebra and interviewed.

Year three

Teachers who attended the PD this year were planning to teach Algebra in the upcoming school year. Fathom software was the focus on the in-person PD. Throughout the following school year, teachers were observed and interviewed, and they also participating in monthly PD opportunities. Over the next school year, the teachers were observed teaching algebra and interviewed.

Data collection and analysis

The goal of the data collection was to document and analyze the decision-making process teachers used concerning the integration of GSP into their geometry and algebra classrooms and Fathom into their algebra classrooms. Observations and teacher interviews, guided by both the TPACK and TAM3 frameworks were used to guide both collection and analysis, further described below. All teachers in each cohort received the same PD and the same broad goal concerning the integration of these new software tools into their classrooms. The data collection effort was designed to understand differences, if any, in actual implementation in the classroom and, based on the guiding theoretical frameworks, the reasons behind these differences or similarities.

Observations took place over the course of each semester during the school year. Teachers and researchers were in communication regularly, and classroom visits were scheduled for when the technology was in use. It should be noted, it was a goal of both the larger school initiative and this project for these teachers to make laptop use a regular part of their classroom activities. Teachers were observed at least twice but sometimes three times during each semester. Three graduate students took responsibility for videorecording the classroom interactions between teachers and students adopting an insider view [emic]. The teacher wore a microphone to better capture what he/she was saying during class.

Brief one-to-one interviews were conducted at the end of each observation for *data triangulation* (Lincoln and Guba 1985). This was an attempt to find out from the teacher how he/she thought the lesson went and add additional context for the lesson taught. In particular, teachers were probed as to their assessment as to how the technology was utilized. More extensive interviews were conducted and videorecorded at the conclusion of each school year. These were lengthy interviews, lasting between 30 and 60 min. These interviews, structured using the TAM3 model (Venkatesh and Bala 2008), probed teachers' perceived usefulness and ease of use, and the underlying reasoning for coming to this stance. The researchers spent time in order to understand teachers' beliefs and perceptions to achieve *prolonged engagement* (Lincoln and Guba 1985).

In aligning with the TAM3 model, the teachers were asked questions based on the four primary determinants that tend to impact their perceived usefulness and *ease of use* of the technology (Table 2). Those areas are: facilitating conditions, system characteristics, social influence, and individual differences. The interview consisted of eighteen (18) initial questions covering the four factors. While most of these items most directly bore on

Table 2 Participant teacher interview items

Primary determinants	Question to address that determinants
Facilitating conditions	How reliable is your network? (0 = never reliable, 7 = always reliable)
	How reliable are your and your students' computers? (0 = never reliable, 7 = always reliable)
	Do you feel you are getting the kind of support you need to use laptops from fellow teachers?
	Do you feel you are getting the kind of support you need to use laptops from support staff?
	Do you feel you are getting the kind of support you need to use GSP/Fathom from fellow teachers?
	Do you feel you are getting the kind of support you need to use GSP/Fathom support staff?
	Do you have the AV/computer equipment you need?
System characteristics	How has your experience been with school-issued laptops? (0 = Very difficult to use, 7 = Problem free and easy to use)
	How has your experience been with GSP and/or Fathom? (0 = Very difficult to use, 7 = Problem free and easy to use)
	Do you think GSP/Fathom helps you teach mathematics the way it should be taught?
Social influence	What are the expectations for your use of laptops/GSP/Fathom from your Department Head/Principal? (1 = expect to use everyday, 2 = use when appropriate, 3 = has not communicated expectations)
	Are other teachers planning innovative activities with laptops/GSP/Fathom?
	Will teaching with laptops/GSP make you a better math teacher?
Individual characteristics	What PD have you received for laptops/GSP?
	On a scale of 0–7 (0 = no experience; 7 = very experienced), what is your level of experience teaching with laptops?
	On a scale of 0–7 (0 = no experience; 7 = very experienced), what is your level of experience teaching with GSP and/or Fathom?
	On a scale of 0–7 (0 = novice; 7 = expert), what is your perceived expertise with computers/software in general?
	On a scale of 0–7 (0 = novice; 7 = expert), what is your perceived expertise with GSP and/or Fathom?

secondary determinants related to perceived usefulness (see Fig. 1), the individual differences questions most immediately aligned with secondary determinants related to perceived ease of use. As noted in the TAM3 model (Fig. 1), perceived ease of use is also believed to directly influence perceived usefulness. The interviews were semi-structured in that, where appropriate, the initial questions led to follow-up probes when opportunities arose to allow teachers to elaborate. Also note that respondents were asked to initially respond to the individual differences/perceived expertise and experience questions with a rating on a scale of 0–7, and to then elaborate. This quantitative data did not meet statistical power requirements for inferential statistics. However, the research questions and data did lend itself to descriptive statistics and effect size calculations for purposes of comparison.

The researchers analyzed the data sets adopting an etic view staying within our frameworks, primarily TAM3. We used a constant comparative analysis outside of grounded theory (Fram 2013) organizing the data within and across the PD years using qualitative data matrices (Bernard and Ryan 2010). For each year, we examined primary factors and sub-factors across teachers using the TAM3 model, and compared and contrasted their perceived usefulness and ease of use of the technology. Afterwards, we compared their perceptions across years to identify the consistencies and changes in their perceived usefulness and ease of use of technology. For this comparison, our secondary framework TPACK model was particularly useful at unpacking these interactions between teachers' curricular goals, preferred teaching strategies, and perceived affordances offered by the software tools. The researchers including one of the co-authors who had conducted some portions of the interviews, were involved in discussions to make decisions about these consistencies and changes that is known *peer debriefing* (Lincoln and Guba 1985).

Findings

The participants of this research used GSP for teaching algebra and geometry, and Fathom for teaching algebra. Accordingly, GSP and Fathom were used as a vehicle for exploring the TAM3 model's constructs of perceived ease of use and usefulness across software and curriculum. While four of the teachers (T11, T12, T17, and T24) in this study used both GSP and Fathom, the researchers will use their responses to each software package to do the comparative analysis. The analysis begins with those questions and responses most directly related to perceived ease of use and then proceeds with those items related to perceived usefulness. Within each of these two sections both research questions will be pursued in a cyclic fashion: Research Question (1) will be addressed with regards to differences in software tools and curricular contexts that emerge, while Research Question (2) will be addressed by looking at the specific factors that seem to be driving these differences.

Ease of use

While perceived ease of use is shaped by many factors, individual differences around self-efficacy towards computer technology, in general, and the software tools GSP and Fathom, in particular, is a critical element. In addition to self-efficacy, the level of experience teachers have with the software tools in the context of their classroom practice is also an important element of perceived ease of use. These two elements are represented in the TAM model in Fig. 1 and the Individual Characteristics items from the interview protocol

(Table 2). The teachers' scale ratings are coupled with their follow-up statements to build a description of the interaction of individual differences and classroom context.

In the first year, the YI (Year 1) participants gave fairly high ratings for their perceived expertise (i.e., self-efficacy) in general computer use ($M = 5.02$), and use of GSP for teaching geometry ($M = 4.73$), in particular. In the second year, the YII teachers reported expertise with GSP that was, overall, lower than the first year cohort ($M = 4.07$; Cohen's $d = -0.49$). Of this YII cohort, the five returning YI teachers indicated a perceived expertise similar to what they reported the first year. Comments from teachers indicate that the extensive classroom implementation required by this project had tempered their relatively optimistic expertise ratings. For example, T9-YI who reported her perceived expertise with GSP 5 out of 7 reflected about her self-confidence by saying: "as far as the functions [e.g., parallel line, angle bisector], I am really comfortable, but I have been watching Youtube videos, and that makes me realize I have a lot to learn." In the second year, T9-YII reported her perceived expertise with GSP at 4.5, and added: "the more I learn the more I realize I need to learn."

The new YII teachers rated their general computer expertise ($M = 4.78$) higher than their expertise with the use of GSP for Algebra quite a bit lower ($M = 3.85$). Unlike GSP, almost none of the teachers had used Fathom before the third year workshop. Even at the conclusion of the school year, the YIII teachers' degree of comfort with using Fathom in algebra was relatively low ($M = 3.84$).

YI teachers reported both relatively high level of experience with laptops in general ($M = 4.86$) and even higher with GSP ($M = 5.70$), paralleling their perceived expertise. These teachers returning in YII reported somewhat higher experience scores for laptop use ($M = 5.88$; $d = .72$) but somewhat lower for GSP use ($M = 5.00$; $d = -.52$). In the second year, new YII teachers reported experience both with laptops ($M = 4.93$; $d = -.66$) and GSP ($M = 4.53$; $d = -.35$) lower compared to the returning YII teachers.

The data for both expertise and experience suggested that when teachers had the opportunity to reflect on their experiences with GSP, it brought up challenges of matching the technology to curricular goals, such as finding relevant curricular activities and that would also be engaging for students. For example, T22-YII reflected her biggest difficulty as "finding stuff that relates to what I am doing…" Similarly, T12-YII stated that "Use of GSP depends on the lesson—some lend themselves towards more GSP—some weeks GSP is used every day of the week, but now with matrices we aren't using GSP this week". Five teachers in the second year pointed to students as key factors utilizing GSP (and thus developing their own experience with it). Some sample answers are given below.

> "…it provides us with something we wouldn't have otherwise. I wish students had access from home, but many don't have that luxury" (T9-YII).
> "…if students are paying attention and understand the tools it is helpful, but they need a lot of repetition" (T12-YII).
> "when I use it in class, the kids know so much. They can figure it out and typically answer their own questions" (T26-YII).

YIII teachers reported the lowest level of experience with Fathom ($M = 3.84$). While some teachers were already familiar with GSP or saw demonstrations or sample lessons using GSP before they participated in the first and second year PD, Fathom was generally a new tool for them. These teachers, in contrast, seemed generally comfortable using GSP, articulating fewer problems during their use of GSP.

Given that self-efficacy towards a software tool may well be contextualized within the curricula they are teaching, it was important to analyze self-efficacy towards GSP use in both geometry and algebra. There is not evidence that indicates the teachers' perceived ease of use of GSP differed in teaching algebra and geometry. When the teachers articulated their self-efficacy with GSP, they refrained from comparing their uses across the curricula (algebra vs. geometry), and answered more generally about the software tool: "I have made a lot of improvement, but I am not where I need to be" (T27-YII). Some teachers referred the challenges they had although they felt it was worth it because they believed GSP helped students learn. While almost all of the teachers agreed the visual feedback of GSP made it relatively easy to use, there were a few specific concerns. For example, one of the teachers wished that GSP had more organized algebraic interfaces.

For most teachers, the third year workshop was the first time using Fathom. For those who had some exposure to Fathom, it was through statistics and probability applications in mathematics. T21-YIII who reported her expertise as 2 out of 7, listed some of her difficulties with Fathom: "I really struggle with importing some of the data—dragging and dropping didn't work—I would get an error code. I ended up just having to type info in by hand." For others, while they felt somewhat comfortable using the software tool in the context of a workshop, making the next step to classroom use was still not within their comfort zone. T31-YIII, who reported in the workshop they were comfortable with using Fathom, stressed that she did not use it in the classroom by saying "even though I haven't used it much in my classroom, I have been playing with it at home trying to get lessons together that just never worked out."

Results of the self-reported ratings of perceived expertise and experience with both computers, in general, and these specific software tools seemed to parallel each other closely. These scores were also parsimonious with the researchers' knowledge of the teachers' prior history with technology. Findings from these interviews seemed to indicate that reported self-efficacy with a software tool was often disconnected from the curricular context in which it would be used, but still seemed to interact with intentions concerning use in the classroom. Use of the software in a workshop setting is not seen as rigorous a test as implementation in the classroom, thus a higher bar of self-efficacy had to be met before teachers were ready to take this step. Thus, lack of confidence in using Fathom was seen as a roadblock for classroom implementation. T11-YIII summed up this situation as follows: "yes, it makes abstract concepts easier. If I were more experienced with it [Fathom], I would use different strategies."

Usefulness

The teachers' perceived usefulness of the software tools for teaching geometry and algebra was another central element determining both intention to use and actual use in the classroom. Perceived usefulness was informed primarily by system characteristics of the software and underlying computer, operating system, and network; social influences of fellow teachers and administrators, and additional facilitating conditions. Data related to these factors were pursued through three sections of the interview protocol: Facilitating conditions (FCs), System characteristics (SCs), and Social influence (SI) (Table 2). It is worth noting that the TAM posits a direct connection between perceived ease of use and usefulness, though in our study the directionality of this relationship was hard to discern. These factors, collectively, often expressed themselves more directly with regards to the perceived ability of the software, as utilized by the teacher, to forward their instructional and curricular goals.

There was ample evidence showing the teachers' beliefs in the usefulness of GSP. Many teachers felt the software furthered their goals by enhancing the learning opportunities for students through improving the quality of instruction:

> "Yes, I think it does. Dynamic capabilities make learning much more broad; with algebra more representations and connections" (T4-YII).
> "It has given me a different perspective to look at things which helps me communicate to the students, I think. I am using it much more frequently this year, whether I am going to get the retention that I would of, I don't have that data yet, so we will see on that. So, I can't say for absolutely sure that it makes me a better teacher…but it has given me some more tools" (T10-YI).

Similarly, T19-YII stressed GSP's potentials by saying "yes—it gives me another resource. It is hard to find good resources because math is math. You just got to sit down and do problems, but you can't do that every day. I think it makes me a more well-rounded teacher." With regards to the impact the software tool had on the student learning experience, the intersection of TCK and TPK revealed itself in a number of ways. Some teachers believed that using GSP did not make them a better teacher, per se, but instead it gave them an opportunity to express their teaching skills in a different way. T27-YII expressed this situation as follows "No, I don't think it has made me better. I just do things differently. The dynamic part of GSP is great." To that end, most teachers believed that GSP changed the way they thought mathematics should be taught:

> "Yes- Students have learned skill-and-drill. GSP is much better because it helps them see the how and why behind it" (T8-YI).
> "Yes, dynamic aspect is 'huge'; ability to show dynamic figures (e.g. Triangle sum theorem) and dynamic functions and how variants and invariants affect functions, and ability to easily test conjectures" (T3-YII).

Some teachers, however, struggled with conceptualizing how old and new pedagogical strategies were going to be integrated. This centered on what the role of paper and pencil methods would be in classrooms using GSP. One of the teachers addressed this situation as follows:

> "I am not sure about this question. Using GSP gives students instant feedback on their geometry ideas. However, most students need to write ideas and have written practice in order to master math concepts" (T7-YI).

In discussing the potential usefulness of Fathom, many teachers more broadly addressed TCK and TPK in terms of the potential of Fathom to change the way mathematics was taught, in general. One of the teachers explained its potential as follows: "The kids enjoy it and it opens up different ways to get them to think. They are able to get control to play around with functions" (T28-YIII). Another teacher explained how she perceived Fathom by saying "yes, it allows them [students] to have more hands-on way of doing things other than giving them a worksheet. Allows for them to manipulate data and visualize" (T12-YIII).

However, when it came to the more specific context of using Fathom in Algebra, they were more reserved in their outlook. Here, we found differences in teachers' perceptions as to whether using GSP or Fathom could help them teach mathematics in the way they thought it should be taught. While teachers believed that both GSP and Fathom were useful, and likely to increase their teaching performance, when they considered these software tools with regard to curriculum, Fathom did not receive the same level of support for teaching algebra as GSP for teaching either algebra or geometry. Teachers felt there was a curricular mismatch with Fathom and it was not very useful for teaching algebra. One of the teachers answered: “there are certain things that Fathom just won’t do. And doesn’t make as much sense due to capabilities and alignment with Algebra curriculum standards” (T12-YIII). Instead, teachers conjectured that Fathom would be particularly useful in Advanced Functions and Modeling, and AP Statistics. There were also a few teachers who thought that Fathom can be used for teaching Algebra II topics. One of the teachers expressed this situation by saying “it would be used more in an AFM or more application based course. In Algebra II there’s not enough time to play” (T29-YIII) Also some teachers stressed the difficulty of aligning curricular algebra activities with Fathom. In addition, some teachers were not satisfied with the online PD they received for teaching and learning algebra using Fathom.

In discussing Fathom with teachers, it was sometimes difficult to disaggregate issues of ease of use from usefulness. Some teachers brought up self-efficacy when discussing its usefulness: “Right now [I’d rate my expertise with Fathom] a ‘1’ and part of that is me. I suspect there are easier ways to apply Fathom other than the course we are doing. As we move into common core, there will be more stats, so then there will be another direct tie.” (T28-YIII). Here we see an example of where statements concerning ease of use are implicitly tied to using the software tool in the context of a particular curricula—in this case, algebra. At other times, the differences in these two factors were clearly separated. As one teacher stressed, that although she felt comfortable using Fathom, she was just challenged creating engaging curricular activities in algebra: “…it isn’t that difficult to use, I just don’t know when to use it” (T24-YIII). While most of the teachers believed as a general principle that Fathom could develop students’ conceptual understanding of mathematical concepts and teaching with Fathom could help them to teach mathematics in the way they thought it should be taught. However, when it came to actually operationalizing Fathom for teaching and learning algebra, it was hard to realize this potential.

Teachers reported logistical challenges of implementing Fathom in the classroom which included time limitations, user-friendliness, and students’ lack of interest or facility with using Fathom:

> “Sometimes it’s user friendly, but sometimes [you] have to have things done to have it do what you want to do (like having to have table selected before being able to do anything with it)” (T12-YIII).
> “I was able to do the first two modules, then the harder it got, it was too difficult with having to teach” (T32-YIII).
> “Students that I taught Fathom with didn’t like it, but that is because they aren’t good with technology in general. When I use it as a demo, it works and they like it” (T31-YIII).
> “I liked it, but my timing was an issue for me. I was always trying to finish stuff up at the last minute” (T21-YIII). “It wasn’t bad, I just couldn’t make time for it” (T24-YIII).

Implicit in many of these statements is the understandable temporally demanding environment which learning and teaching goals are being enacted. The perceived lack of curricular alignment and the manifested usability issues created a time penalty that ruled out its usefulness to fulfill these time-sensitive goals.

The more widespread adoption of GSP, both within the project cohort and outside of it, meant that most teachers had support from their fellow the teachers for GSP and collaborated on lesson planning and general software use. One of the teachers emphasized this situation by saying "Yes, Mrs. Williams (pseudonym) and I are a team when it comes to teaching geometry at our school. She has been extremely helpful and patient as I learn to use GSP" (T7-YI). For many of these teachers there were also expectations of using laptops, in general, from their principals and department heads:

> "I would say that Mrs. White (pseudonym) understands there are some things that are not appropriate for a laptop, but she does expect very frequent use of technology… We are expected to be using technology in the majority of our time" (T10-YI).
> "Principal wants the teachers to use them frequently, but he understands that some courses lend themselves to needing the laptops more often than others" (T1-YI).

Although school administrations expected the teachers to use laptops when appropriate, the teachers mostly did not communicate with administrators about their specific use of software, such as GSP or Fathom, in the classroom. While teachers reported little concerns with support for school laptops and the network, they assumed they would need to look to their fellow teachers for specific software support. Teachers felt they had little support from their IT staff, in part because these staff did not know how to use math-specific software.

The teachers expressed some new external pressures in the last year of the project. The most common factor was the new state standards for mathematics that were being implemented with little perceived support on how to implement the new curricula. These new curricular changes only increased time pressures on teachers and exacerbated a feeling there was no time to experiment with new tools that did not have direct applicability to their new mandate:

> "New textbook…which required all new assessments, new order of teaching, new post/end-of-year state mandated assessments that were introduced for first time and unclear expectations of tested content, new Common Core curriculum, new style of teaching…GSP was a product that everyone bought into, but Fathom was seen as less applicable and could be done with TI calculators" (T29-YIII).
> "I don't have time to learn the new curriculum. More standards. And having no one else to talk to" (T27-YIII).
> "New curriculum and having to pace it. Also, we use performance events, which was a requirement and added pressure. Also, had to be done as a department so I couldn't even use Fathom" (T11-YIII).

The new mathematics curricular standards were yet another "moving part" driving uncertainty about integrating Fathom into algebra classrooms. These concerns often seemed to be expressed in terms of time needed for implementing both curriculum and technology in the classroom. Ironically, while teachers such as T28-YIII noted that the new standards were likely to bring mathematical concepts into algebra that Fathom could support, in the short run, there was not time to be experimenting with software whose payoff was still perceived as being too far off into the future.

Discussion and implications

This study was guided by two research questions regarding the differences seen in perceived ease of use and usefulness of two student mathematics learning software tools, GSP and Fathom, and the likely underlying causes for these differences. From this research, a strong contrast emerged from the analysis between the perceived usefulness and ease of use of GSP and Fathom in mathematics classrooms. The two primary themes underlying this contrast that emerged were: (1) the teachers' comfort level with using the software tools in a classroom context and how this interacted with their perceived ease of use, and (2) their understanding of the software's capabilities and alignment with their curricular and teaching goals. Ultimately, this alignment became the over-riding factor driving perceived usefulness. Secondary factors influencing perceived usefulness included alignment with preferred pedagogical strategies and support from fellow teachers. This last factor probably also crossed over to perceptions of ease of use.

One of the factors that made a difference in software use was the teachers' and students' comfort level with using each technological tool, and their level of experience and familiarity. The teachers had higher perceived expertise and more experience with using GSP than with Fathom. Collectively, this spoke to higher self-efficacy in terms of teachers' ability to effectively deploy GSP as an instructional tool. Handal et al. (2013) also found that teachers had a higher degree of comfort using dynamic geometry software than computer algebra software—a reminder that teachers' perceived ease of use may vary from software to software, even within a disciplinary area. Previous research has shown conflicting results on teachers' experiences and degree of comfort with the use of technology. While Forgasz (2006) and Thomas (2006) found this as one of the important factors that influenced teachers' uses in the classroom, Stols and Kriek's (2011) research indicated that teachers' confidence with technology (i.e., perceived ease of use) was not a significant factor on teachers' attitudes towards using it. In the aforementioned research, data were collected only with a questionnaire and interview 3 months after a workshop. The current research, demonstrating a connection between perceived ease of use and usefulness, and actual classroom use over an entire year (or years), may account for the differences seen with Stols and Kriek's (2011) study.

Perceived usefulness of technology was the other contrasting facet between the software. The teachers believed that using GSP in algebra and geometry could increase their performance. However, they did not hold the same belief in using Fathom for teaching algebra. Although they believed that Fathom was a visually-rich tool, and can increase students' conceptual understanding (in general), they consistently referenced the curricular mismatch of Fathom with algebra. In other words, one of the most important distinctions between the software tools was its relevance to curricular objectives. It was important to disaggregate perceptions self-efficacy and usefulness expressed in more abstract terms and when asked to predict or reflect on use in specific contexts (such as an Algebra I classroom). Similar to previous research (e.g. Handal et al. 2013), curricular factors played a major role for the use of technology in the classroom. Almost all teachers stressed the difficulty of aligning Fathom with the algebra curriculum, and instead recommended using it for teaching and learning in later classes, such as Advanced Functions and Modeling or AP Statistics. On the other hand, the teachers did not identify such problems using GSP for teaching and learning in either geometry or algebra, expressing a perceived high degree of alignment. The underlying software design of GSP and Fathom embedded different explicit and implicit instructional philosophies in mathematics lessons. The requirements for having data sets to "drive" Fathom may have been seen as an unfamiliar pedagogical approach to teachers. Such pedagogical requirements may have increased their perception of a curricular mismatch. These findings on the centrality of concerns around curricular alignment and the need for the software to further their instructional goals aligns with Stols and Kriek's (2011) mathematics education research indicating that teachers' perceived usefulness of technology was a strong estimator towards its eventual use.

Time issues, particularly for using Fathom, was raised as a major obstacle for the teachers to implement it into the curriculum. Again, it was often difficult to disaggregate issues of ease of use from usability regarding temporal issues. Was it lack of expertise with the software that led to perceptions of longer instructional time being needed, or was the general pedagogical or curricular misalignment leading to inefficiencies in achieving instructional goals? In addition, other external factors, such as newly enacted state standards, students' capacity (e.g., lack of attention), and other logistical concerns were listed as reasons for low use of Fathom in the classroom. Once more, it was difficult to discern whether these additional factors amounted to post hoc rationalizations for lack of use or true, underlying additive causes. Although previous research (e.g., Forgasz 2006; Handal et al. 2013) indicated lack of computers/software as one of the most common barriers, in the current research, such factors were not considered as important because school districts had already established technology-rich classrooms. It is unclear how much logistical factors and other external distractions were primary drivers for lack of use of Fathom since many of these were also in place when GSP was being used. One suspects that temporal pressures factored heavily, and was used by the teachers as a proxy for there lack of comfort with finding ways to integrate the tool and align with the curricular goals. This was likely also influenced by a stronger organizational support community for GSP use than for Fathom use. That is, there was acknowledged support from peers for "taking time" to use GSP, because of its perceived alignment to school goals. This support was not seen with Fathom.

Through the interviews, it became clear that a number of factors came into play when teachers made decisions concerning the ease of use and usefulness of both GSP and Fathom. Both prior exposure to GSP, peers' use of the tool, and their beliefs concerning their ability to use it pedagogically in efficacious ways influenced their perceptions of ease of use. In direct contrast, direct or indirect prior exposure to Fathom was low, in addition to teachers' struggles in conceiving how it could be effectively used as a pedagogical tool. This resulted in low self-efficacy and poor perceived ease of use. This contrast between software tools provided robust evidence that perceptions of usefulness, especially in terms of curricular alignment, was well aligned with the TAM and the outcome variable of the model: actual use of the software. In the case of GSP, perception of usefulness was high as was its use in the classroom. Fathom provided the opposite case. In both cases, lack of prior use or modeling by other teachers reinforced these beliefs about utility and self-efficacy with regards to both the software tool itself and its use as a teaching and learning tool.

These findings also emphasize the complex relationship of perceived usefulness and perceived ease of use. While the TAM3 model indicates a one-way arrow with perceived ease of use influencing usefulness, our study points to a more complex relationship with regards to self-report of these constructs. That is, teacher's perceptions of ease of use went beyond simply using the software tool itself and contextualized the tool within the task of teaching. Poor curricular alignment (usefulness) meant that it would be more difficult to implement (ease of use). Temporal pressures also exacerbated perceived ease of use, creating a more high stakes environment in which to effectively demonstrate the usefulness of the software tool. Lack of time in the classroom meant that lack of expertise was penalized just as lack of time outside of the classroom limited a teachers' ability to overcome these expertise hurdles.

While all of these findings could be analyzed exclusively through the TAM, the TPACK model was particularly useful at unpacking these interactions between teachers' curricular goals, preferred teaching strategies, and perceived affordances offered by the software tools. TPACK became an important lens in the context of classroom instruction for unpacking perceived usefulness of the software tools, by teachers, in the context of specific mathematics courses, and its interaction with perceived ease of use. Historically, the TAM was developed in non-educational work setting and is silent on issues directly pertaining to teaching and learning. TPACK positions the teachers' interpretive lens of the usability of the software in terms of not only the tool in isolation, but usability in the context of specific learning goals and pedagogical strategies they wish to utilize. Therefore, self-efficacy in this context cannot be interpreted in terms of strictly software use, but in terms of a teacher's self-efficacy to deploy specific pedagogical strategies using the software tool in order to achieve targeted learning goals. Thus, this study has demonstrated how the TPACK model informs TAM model utilization regarding the dual importance of both perceptions of software mastery and pedagogical mastery when deploying the software as a teaching and learning tool.

Nested within the TAM model, these perceptions bear not only on the perceptions of usability and but also perceived usefulness. In fact, teachers' interpretation of the ability to utilize specific pedagogical strategies with a software tool may be seen as largely an issue of usefulness of the software to achieve specific learning goals. The fact that the empirical results of this study questioned whether statements regarding the usability of Fathom may be as much the result of its perceived lack of usefulness may open the question as to whether the TAM model (Fig. 1), applied in this instructional context, may be best represented by a bidirectional arrow between perceived usability and perceived usefulness. Again TPACK helps guide this finding by pointing out that inextricable link between technology tool and pedagogy makes it more difficult to separate perceptions of the usability of the software from perceptions of its usefulness to further pedagogical strategies. In a complementary fashion, TAM was instrumental in putting decision-making by teachers into the context of a larger organization of interrelated human and technology systems. Teachers' discussion of time constraints on instruction and end of course high stakes test can be linked to and help interpret statements regarding both usability and usefulness of the software relative to specific pedagogical strategies and student learning goals. Similarly, the study has also broadened our understanding of how the TAM generalizes to instructional settings such as K-12 classrooms, increasing the theoretical base from which to study technology integration in the classroom.

The results of the current research study suggest new implications for future teacher professional development. As we have found, teachers had higher self-efficacy on GSP than Fathom, which influenced their planned and actual implementation. In this context, teachers should be given a longer period to become familiar with technology with active engagement and group collaborations among mathematics teachers. Like students, teachers learn better by doing, investigating, and sharing mathematics (Loucks-Horsley et al. 1996). Learner-centered professional development is as an important factor for supporting teachers' technology enactment (Polly and Hannafin 2010).

Similarly, organizational support in terms of school-based cohorts for mutual support and more planning time to reduce temporal stresses could be important factors for successful implementation. Teachers reported collaboration with fellow teachers designing curricular activities using GSP but little on Fathom. Lack of time may still undercut both teachers' collaboration (Hew and Hara 2007) and the desire to experiment with classroom implementation. Finally, prior research has noted the importance of student responses to, and behaviors with, technology in the classroom with regards to shaping a teacher's perceptions and eventual utilization of technology Angeli and Valanides 2009). Future research should also attempt to integrated student-centric data in addition to teacher-centric sources.

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References

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: advances in technological pedagogical content knowledge (TPCK). *Computers & Education, 52*(1), 154–168.

Argueta, R., Huff, J. D., Tingen, J., & Corn, J. (2011). *1:1 Laptop initiatives: a summary of research findings across six states White Paper Series*. Raleigh: Friday Institute for Educational Innovation, North Carolina State University.

Behrend, T. S., Wiebe, E. N., London, J., & Johnson, E. (2011). Cloud computing adoption and usage in community colleges. *Behaviour & Information Technology, 30*(2), 231–240. doi:10.1080/0144929X.2010.489118.

Bernard, H. R., & Ryan, R. W. (2010). *Analyzing qualitative data: systematic approaches*. Thousand Oaks: Sage Publications.

Bourgonjon, J., Valcke, M., Soetaert, R., & Schellens, T. (2010). Students' perceptions about the use of video games in the classroom. *Computers & Education, 54*(4), 1145–1156. doi:10.1016/j.compedu.2009.10.022.

Cavanagh, M., & Mitchelmore, M. (2011). Learning to teach secondary mathematics using an online learning system. *Mathematics Education Research Journal, 23*(4), 417–435. doi:10.1007/s13394-011-0024-1.

Common Core State Standards Initiative (CCSSI). (2012). Standards for mathematical practice. Retrieved from http://www.corestandards.org/Math. Accessed 5 Dec 2012.

Compeau, D. R., & Higgins, C. A. (1995). Computer self-efficacy: development of a measure and initial test. *MIS Quarterly, 19*, 189–211.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319–339.

Doerr, H. M., & Zangor, R. (2000). Creating meaning for and with the graphing calculator. *Educational Studies in Mathematics, 41*(2), 143–163.

Drayton, B., Falk, J. K., Stroud, R., Hobbs, K., & Hammerman, J. (2010). After installation: ubiquitous computing and high school science in three experienced, high-technology schools. *Journal of Technology, Learning and Assessment, 9*(3), 5–56.

Forgasz, H. (2006). Factors that encourage or inhibit computer use for secondary mathematics teaching. *Journal of Computers in Mathematics and Science Teaching, 25*(1), 77–93.

Fram, S. (2013). The constant comparative analysis method out- side of grounded theory. *The Qualitative Report, 18*, 1–25.

Goos, M., Soury-Lavergne, S., Assude, T., Brown, J. P., Kong, C. M., Glover, D., et al. (2010). Teachers and teaching: theoretical perspectives and issues concerning classroom implementation. In C. Hoyles & J. B. Lagrange (Eds.), *Mathematics education and technology-rethinking the terrain* (pp. 311–328). New York: Springer.

Graham, C. R., Borup, J., & Smith, N. B. (2012). Using TPACK as a framework to understand teacher candidates' technology integration decisions. *Journal of Computer Assisted Learning, 28*(6), 530–546. doi:10.1111/j.1365-2729.2011.00472.x.

Handal, B., Campbell, C., Cavanagh, M., Petocz, P., & Kelly, N. (2013). Technological pedagogical content knowledge of secondary mathematics teachers. *Contemporary Issues in Technology and Teacher Education, 13*(1), 22–40.

Harris, J. B., & Hofer, M. J. (2011). Technological pedagogical content knowledge (TPACK) in action: a descriptive study of secondary teachers' curriculum-based, technology-related instructional planning. *Journal of Research on Technology in Education, 43*(3), 211–229.

Harris, J. B., Mishra, P., & Koehler, M. (2009). Teachers' technological pedagogical content knowledge: curriculum-based technology integration reframed. *Journal of Research on Technology in Education, 41*(4), 393–416.

Hegedus, S. J., Tapper, J., & Dalton, S. (2016). Exploring how teacher-related factors relate to student achievement in learning advanced algebra in technology-enhanced classrooms. *Journal of Mathematics Teacher Education, 19*(1), 7–32.

Hew, K. F., & Hara, N. (2007). Empirical study of motivators and barriers of teacher online knowledge sharing. *Educational Technology Research and Development, 55*(6), 573–595.
Hollebrands, K., & Zbiek, R. (2004). Teaching mathematics with technology: an evidence-based road map for the Journey. In R. Rubenstein & G. Bright (Eds.), *Perspectives on the teaching of mathematics: sixty-sixth yearbook* (pp. 259–270). Reston: National Council of Teachers of Mathematics.
Kim, C., Kim, M. K., Lee, C., Spector, J. M., & DeMeester, K. (2013). Teacher beliefs and technology integration. *Teaching and Teacher Education, 29*, 76–85. doi:10.1016/j.tate.2012.08.005.
Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education, 9*(1), 60–70.
Lee, H. S., & Hollebrands, K. F. (2011). Characterising and developing teachers' knowledge for teaching statistics with technology. In C. Batanero, G. Burrill, & C. Reading (Eds.), *Teaching statistics in school mathematics-challenges for teaching and teacher education* (pp. 359–369). New York: Springer.
Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Thousand Oaks: Sage.
Loucks-Horsley, S., Stiles, K., & Hewson, P. (1996). Principles of effective professional development for mathematics and science education: a synthesis of standards. *NISE Brief, 1*(1), 1–7.
Manfra, M. M., & Hammond, T. C. (2008). Teachers' instructional choices with student-created digital documentaries: case studies. *Journal of Research on Technology in Education, 41*(2), 223–245.
Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: a framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054.
Moore, G. C., & Benbasat, I. (1991). Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research, 2*(3), 192–222.
Nastasi, B. K., & Schensul, S. L. (2005). Contributions of qualitative research to the validity of intervention research. *Journal of School Psychology, 43*(3), 177–195.
National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston: NCTM.
National Council of Teachers of Mathematics. (2009). *Focus on high school mathematics: reasoning and sense making*. Reston: NCTM.
National Council of Teachers of Mathematics. (2014). *Principles to actions: ensuring mathematical success for all students*. Reston: NCTM.
Ng, W. (2012). *Empowering scientific literacy through digital literacy and multiliteracies*. New York: Nova Science Publishers.
Nistor, N., Göğüş, A., & Lerche, T. (2013). Educational technology acceptance across national and professional cultures: a European study. *Educational Technology Research and Development, 61*(4), 733–749. doi:10.1007/s11423-013-9292-7.
Norton, S., McRobbie, C. J., & Cooper, T. J. (2000). Exploring secondary mathematics teachers' reasons for not using computers in their teaching: five case studies. *Journal of research on computing in education, 33*(1), 87–109.
O'Connor, M. K., Netting, F. E., & Thomas, M. L. (2008). Grounded theory: managing the challenge for those facing institutional review board oversight. *Qualitative Inquiry, 14*(1), 28–45.
Polly, D. (2011). Examining teachers' enactment of technological pedagogical and content knowledge (TPACK) in their mathematics teaching after technology integration professional development. *Journal of Computers in Mathematics and Science Teaching, 30*(1), 37–59.
Polly, D., & Hannafin, M. J. (2010). Reexamining technology's role in learner-centered professional development. *Educational Technology Research and Development, 58*(5), 557–571.
Segall, A. (2004). Revisiting pedagogical content knowledge: the pedagogy of content/the content of pedagogy. *Teaching and Teacher Education, 20*(4), 489–504.
Shulman, L. S. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14.
Shulman, L. S. (1987). Knowledge and teaching: foundations of the new reform. *Harvard Educational Review, 57*(1), 1–22.
Spires, H. A., Wiebe, E. N., Young, C. A., Hollebrands, K., & Lee, J. K. (2012). Toward a new learning ecology: professional development for teachers in 1:1 learning environments. *Contemporary Issues in Technology and Teacher Education, 12*(2), 232–254.
Stake, R. E. (1995). *The art of case study research*. Thousand Oaks: Sage.
Stols, G., & Kriek, J. (2011). Why don't all maths teachers use dynamic geometry software in their classrooms? *Australasian Journal of Educational Technology, 27*(1), 137–151.
Sun, H. S., & Zhang, P. (2006). The role of moderating factors in user technology acceptance. *International Journal of Human-Computer Studies, 64*(2), 53–78. doi:10.1016/j.ijhcs.2005.04.013.

Swan, B., & Dixon, J. (2006). The effects of mentor -supported technology professional development on middle school mathematics teachers' attitudes and practice. *Contemporary Issues in Technology and Teacher Education, 6*(1), 67–86.

Tabach, M. (2011). A mathematics teacher's practice in a technological environment: a case study analysis using two complementary theories. *Technology, Knowledge and Learning, 16*(3), 247–265.

Thomas, M. O. J. (2006). Teachers using computers in mathematics: A longitudinal study. In J. Novotná, H. Moraová, M. Krátká, & N. Stehlíková (Eds.), *Proceedings of the 30th annual conference of the international group for the psychology of mathematics education* (Vol. 5, pp. 265–272). Prague: Charles University.

Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences, 39*(2), 273–315.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: four longitudinal field studies. *Management Science, 46*(2), 186–204.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: toward a unified view. *MIS Quarterly, 27*(3), 425–478.

Wiebe, E. N., Williams, L., Yang, K., & Miller, C. (2003). *Computer science attitude survey*. Raleigh: Department of Computer Science, North Carolina State University.

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