Vallett, D., Annetta, L., Lamb, R., & Bowling, B. (2014). Diffusing innovations: Adoption of serious educational games by K-12 science teachers. *Contemporary Issues in Technology and Teacher Education*, *14*(3), 247-265.

Diffusing Innovations: Adoption of Serious Educational Games by K-12 Science Teachers

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ABSTRACT

Innovation is a term that has become widely used in education; especially as it pertains to technology infusion. Applying the corporate theory of diffusing innovation to educational practice is an innovation in itself. This mixed-methods study examined 38 teachers in a science educational gaming professional development program that provided baseline characteristics about personal technology use and post professional development workshop experiences to ascertain characteristics that align with diffusion of innovation theory and educational game development as a new innovation in current pedagogical practices. The posttest-only design tested correlation (ANOVA) between factors, following scale conversion employing Rasch modeling, using the established Ocean Explorers workshop survey to collect data. Results suggested that while none of the demographic factors were significantly correlated with participant perceptions of the workshop, participants' perceptions of the presentation of the material were strongly correlated to their perceptions of the opportunities afforded by the workshop and the level of technological pedagogical content knowledge learning that took place. Frequencies of response ranges from the survey, for each scale, were paired with qualitative data to propose a fit to Rogers' innovation adoption curve and provide a richer description of participant perceptions. Additionally, the findings from this study serve as a framework for professional development of innovative educational technologies for subsequent studies.

Online or electronic gaming is a growing technology being used by many students at all grade levels. According to a recent Electronic Software Association (ESA) report, 58% of the US population participated in video gaming in 2012, with combined formats (console, computer, mobile phone, and other mobile technologies) totaling $14.8 billion in sales (Electronic Software Association, 2013).

Children under age 18 represented 32% of gaming participants, equaling 18- to 35-year-olds. They ran a close second to gamers aged 36+ years, who made up 36% of the gaming population. Gamers were slightly more likely to be male (55%) than female (45%), but women 18 or older made up a greater proportion of the gamer population than males 17 or under (31% and 19%, respectively; ESA, 2013).

According to Stansbury (2008), 64% of K-12 students reported they play online or electronic-based games about 8 to 10 hours per week on average. Thus, serious educational games (SEGs) have become an interesting technological tool for current pedagogical use in educational environments. SEGs are defined as games that immerse learners in an experience that embeds essential content, rather than being explicitly learning based or explicitly entertainment, like their edutainment and commercial compatriots (Annetta, 2008).

More than 50% of students in grades 3-12 have reported that they would like to see more educational gaming in their schools, but only 19% of parents and 15% of administrators have reacted favorably to that idea (Stansbury, 2008). As few as 1 in 10 teachers have currently adopted educational gaming as an instructional tool in the classroom. Successful adoption of SEGs as an instructional material depends on teachers' technological pedagogical content knowledge (later referred to as technology, pedagogy, and content knowledge, or TPACK), defined by Mishra and Koehler (2006) as the understanding of how to integrate technology with subject matter knowledge and pedagogical skills.

The purpose of this study was to examine teachers' perceptions of adopting innovations (in this case, SEGs), the opportunities afforded by professional development, and their perceptions of TPACK as related to the implementation of SEGs, following an extended professional development in classroom implementation of SEGs.

SEGs are still a predominantly untapped pedagogical resource, because many educators still perceive SEGs as frivolous technologies with little to no educational value. Teachers often lack the skills and knowledge to integrate technology effectively into the classroom and, thus, are still using computers primarily for administrative tasks rather than as teaching tools (Becker, 2007). Preparing teachers to use technology effectively in the classroom is critical.

While researchers explore ways to use technological tools such as SEGs in the classroom and their impact on learners, this information rarely makes it into the hands of the practicing teachers who typically do not read the research journals (Sprague, 2004). Sabelli (2006) recommended that curriculum be reorganized around complex scientific issues (instead of disciplines) and use innovative educational approaches to examine these complex issues.

According to Friedman (2005), the educational research community needs to study those pedagogical methodologies that will engage young learners, particularly in science. Friedman posited that combining what students do outside of school with what they do inside the classroom is a critical step in the right direction toward engaging and motivating students to succeed in an economically diverse world.

To this end, the primary thrust of this study's project is to foster teacher interest through professional development on how to design, create, and effectively integrate SEGs into their respective science classrooms as a way to engage students in science, which will ultimately impact achievement.

According to Dewey (1916), pedagogy must evolve in order to ensure students are continually provided meaningful learning opportunities. One important goal of education is to prepare the learner with the knowledge and skills necessary to succeed in life.

In the current economic environment, education also plays a critical role in maintaining and stimulating economic growth (Stevens & Weale, 2003). Markets in this new economy are rewarding people who have high educational achievements and vast technical skills (Task Force on the Future of American Innovation, 2005). Furthermore, businesses are hiring people who can think critically, adapt to their surroundings, and quickly respond to unforeseen problems. From an epistemological standpoint, these skills are necessary in problem-based learning environments. For example, when learners are given a set of problems with clearly defined goals, they must be able to adapt quickly to their surroundings by critically analyzing new situations and interacting with other learners to solve the given problems.

Rogers (2003) introduced the innovation adoption curve to illustrate the camber of technological adoption. The categories of the adoption curve were defined as follows:

- Innovators are brave people pulling the change who serve as important communication mechanisms for the new technology.
- Early adopters are respectable people who try out new ideas in a careful way and serve as leaders for popular opinion regarding the new technology.
- Early majority are thoughtful people who accept change more quickly than average people do.
- Late majority are skeptical people who will use new ideas or products only when the majority is using it.
- Laggards are traditional people who are critical about new ideas and do not adopt the new technology easily.

As shown in Rogers' innovation adoption curve, certain percentages of people fall into the aforementioned categories based on terms of their willingness to adopt new technologies. Specifically, Rogers identified adopters as falling into categories of Innovators (2.5%), Early Adopters (13.5%), Early Majority (34%), Late Majority (34%), and Laggards (16%). In the study reported in this paper, the categories and percentages from the innovation adoption curve were used as guidelines to identify groups of teachers for the purposes of professional development in educational game design.

Rogers (2003) defined diffusion as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (p. 35). Additionally, Rogers defined adoption as, "an idea, practice or object perceived as new by an individual" (p. 36). Three types of innovation-decisions can be diffused, or communicated, across the curve.

- Optional innovation-decisions, which are made by individuals who are in some way distinguished from others in a social system.

- Collective innovation-decisions, which are made collectively by all individuals of a social system.
- Authority innovation-decisions, which are made for the entire social system by a few individuals in positions of influence or power.

Thus, the members of a social system are responsible for the adoption of technological innovations through these communication networks.

Rates of diffusions and subsequent adoption depend on how the proposed technology interacts with certain aspects of the targeted population. These interactions include the following five processes:

- Knowledge includes exposure to the technology's existence and understanding of its functions.
- Persuasion involves the forming of a favorable attitude toward the technology.
- Decision constitutes a commitment to the technology's adoption.
- Implementation includes putting it to use.
- Confirmation involves reinforcement based on positive outcomes from it the use of the technology.

The progress of new technology through these stages can be hindered (or halted altogether) if any one of the phases is not satisfactorily met by the social system. According to Rogers (2003), social systems consider the following indicators as innovations pass through the five phases. The relative advantage of new technology is the improvement over the previous generation. The level of compatibility of an innovation involves its assimilation into an individual's life. The complexity of an innovation plays a role in whether it is adopted by an individual. For example, if the innovation is too difficult to use, then an individual will not likely adopt it.

Trialability describes how easily an innovation may be tested while users are adopting it. For instance, if a user has a hard time trying an innovation, then they will be less likely to adopt it. Finally, observability involves the extent to which an innovation is visible to others. Thus, an innovation that is more visible will drive communication among the individual's peers and personal networks (Rogers, 2003).

Sometimes innovations are disruptive. A disruptive innovation is worse than the current technology, but is still used by the target audience for a number of reasons (Rogers, 2003). In education, disruptive innovations are not uncommon when they pertain to technology. Often, there are better products than what schools can afford, maintain, or network. Hence, many schools take on a disruptive innovation that is simpler and more affordable than similar products available on the market but is still an improvement to their current technology.

Cook (2008) stated that problem-based learning environments enhanced with current gaming technology provide learners with multiple opportunities to practice real world tasks in digital spaces, fail at difficult challenges in an educational setting, and safely learn from these failures in order to become more competent learners. Additionally, Christensen and Horn (2008) suggested that a network of educational software developed by fellow teachers, students, and parents would emerge as a solution to the limited resources currently available at all levels of education. These principles served as the foundation for the HI FIVES (Highly Interactive Fun Internet Virtual Environments in Science) project, which explored the relationship between student learning and the use of SEG technology in science and mathematics.

The primary goal of the HI FIVES project is to instruct science and mathematics teachers in grades 5-9 about game theory, game design, and how effectively to infuse difficult content and integrate SEGs into their respective curricula. A software application was created to make game construction less intrusive through a drag-and-drop method. The same application also served as a repository for the games created that will eventually be made available for use by other teachers and students. The study reported in this paper was part of the HI FIVES project that focused on introducing educational game design to teachers in a professional development setting and their willingness to adopt this new technological innovation in their current classrooms.

Rationale for the Study

Rapid changes within the field of instructional technology necessitate a commitment to ongoing and sustained professional development opportunities. All professional development should model and include the use of current and emerging technology resources. Professional development that does not focus on the ongoing classroom duties of the teacher show little, if any, impact on teaching practices or student achievement (Zigmarmi, Betz, & Jennings, 1977).

Without a strong commitment from the educational community, professional development of teachers will not yield successful implementation of new innovations (CELT, 1997). Digital learning is critical to preparing students with the necessary technological and critical thinking skills to succeed in the 21st century (CEO Forum, 2000, June). Therefore, teachers must be prepared with the latest educational innovations, and the innovators and early adopters must push the diffusion of those innovations across the curve.

According to Loucks-Horsley and colleagues (2010) and Dori and Barnea (1994), proper in-service training increases the effective use of new technologies in the classroom. Their study on teacher professional development using technology reported that teachers with over 20 years of classroom experience perceived the use of technology for science professional development to be more effective than teachers with 16–20 years of classroom experience. Thus, teachers with more classroom experience see the changing dynamics of their students and understand the critical nature of changing their practice to meet the needs of today’s more technological advanced students. Hence, teachers with more classroom experience might fall into the early adopter or innovator category. Despite the counterintuitive nature of these findings, Dori and Barnea’s work was supported in the Annetta and Matus (2004) study with distance learning technologies.

Many teacher professional development programs employ the transmission model of education in which teachers passively receive knowledge and skills from “experts” that provide training. This model is often mirrored with smaller interventions, wherein the initially selected teachers are then deemed experts and required to transmit the knowledge to the remainder of the faculty. In contrast, more profound professional development takes place within a sustained community of teachers and other professionals who share resources, support one another, and serve as mutual role models around a common goal or enterprise (Barab, Makinster, & Scheckler, 2004). In the study reported here, this sustained community of teachers represents the targeted social system discussed by Rogers (2003).

Teachers must be able to integrate new technological skills into both subject matter and pedagogical practices, a comprehensive set of competencies known as TPACK (Mishra & Koehler, 2006). As seen in Figure 1, TPACK is represented by the intersection of the three circles representing pedagogical knowledge, content knowledge, and technical knowledge. The size of the overlap indicates the extent to which a teacher has developed an integrated understanding of the complex relationships between subject matter, pedagogical goals, and available technologies.

In general, high levels of TPACK indicate that the teacher not only knows the content, but understands how to successfully teach it using technological tools. The TPACK framework illustrates that training teachers on how to use technology is not sufficient for effective implementation. Rather, teachers must be given opportunities to develop appropriate, context-specific strategies for integrating technology into their teaching practices (Mishra & Koehler, 2006).

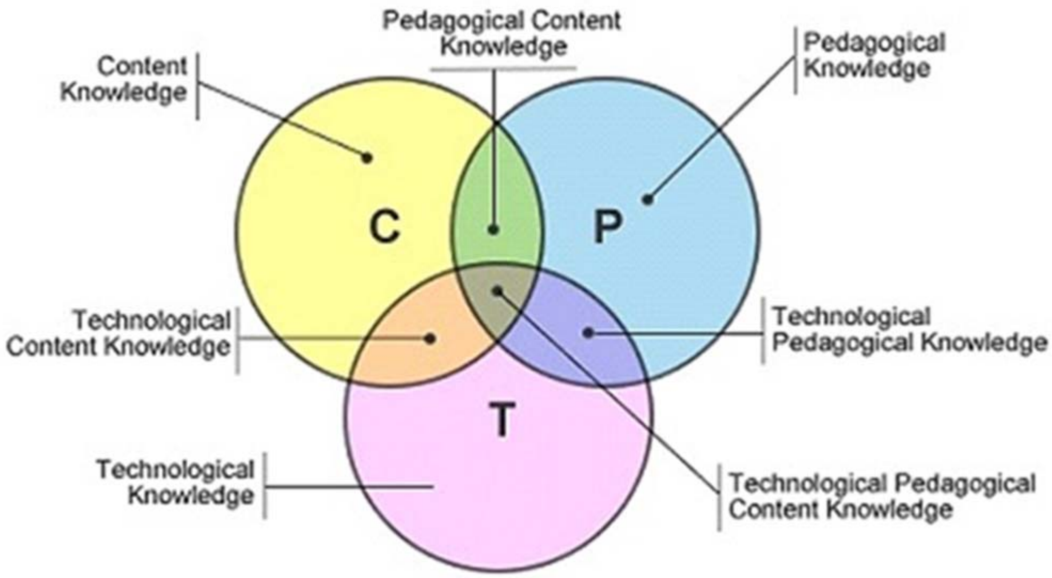


Figure 1. *TPACK model from Mishra and Kohler (2006).* Reproduced by permission of the publisher, © 2012 by tpack.org

Brown (1992) suggested that effective student projects focused on enhancing student learning involved carrying out design work, researching its implementation, reproducing the results into future design iterations, and reexamining how these innovations impact the learning process. A similar approach in the context of teacher professional development requires teacher educators to adopt a willingness to change the nature, structure, and even the assumptions of their professional development programs in response to cyclic evaluation data, ongoing participants' experiences, and participants' reflections. In other words, this approach requires teachers to be more like innovators rather than laggards (Brown, 1992; Rogers, 2003).

Generally, teachers who have not had professional development using innovative technologies are apprehensive about including technology as a seamless component of their respective instructional arsenal. Therefore, the current challenges for professional development programs are finding ways to effectively train teachers in using new innovations, providing continual support of the new innovations to the teacher, and producing a move of each teacher toward an early end to the innovation adoption curve by becoming more of an innovator.

The professional development model for this study was designed to leverage the findings previously discussed, with particular attention paid toward the impact of a more constructivist, social model of learning on perceptions of TPACK, willingness to adopt innovation, and perceptions of the workshop in general.

Niess, van Zee, and Gillow-Wiles (2010) identified effective strategies for technology-oriented professional development by extending pedagogical content knowledge to TPACK; specific goals included incorporating knowledge of the use of the technology into teachers' knowledge of content, curriculum materials, and student cognition. Prior studies linked teachers' exploration of TPACK with their experiences with technology, in and out of professional development, but did not make the jump to considering their overall acceptance of adopting technology or their perceptions of the workshop environment.

Research Question

The implementation of innovative technology in the classroom is dependent upon teachers' TPACK, their stance on adopting innovations, and their opportunity to combine innovative technology with relevant curricular content. Based on these current challenges to implementation of innovations in the classroom, this study sought to explore the following research question: What are the relationships between perceptions of TPACK, teacher's placement on the innovation adoption curve, and perception of workshop environment after receiving professional development about infusing innovative technology into the classroom?

It is important to note that although this study used SEGs, it is an example of how currently practicing science teachers react to innovative technologies in their classroom. We predicted that results should suggest implications for infusing professional development practices with any new technology, not just SEGs.

Methods

This design-based methodology provided teachers with the opportunity to learn how to use educational gaming technologies situated in the context of their specific content area and grade level (Barab & Squire, 2004). Design-based research adjusts the context and content of the study through formative evaluation of the study parameters, in this case the delivery of the professional development.

Ultimately, the professional development program focused on the current standards in science and mathematics at respective grade levels in order to incorporate seamlessly the educational game into the teachers' current pedagogical practices. Thus, teachers were initially asked to create a problem-based scenario that they either already used in their classroom or to create one that aligned with the current state science and mathematics content standards.

Treatment

Teachers were exposed to a train-the-trainers professional development model, wherein five initial volunteer teachers in the program became experts, who were then directed to diffuse the innovation of game design through the use of software previously developed for this purpose. These 5 teachers worked collaboratively with 10 new teachers who then, in turn, worked with an additional 60 teachers. These additional 60 teachers were split into an initial group (n = 22) and a final group (n = 38).

Over a 3-year period, all groups of teachers participated in two 40-hour weeklong workshops during the summer months and four 4-hour workshops throughout the academic year, with the goal of teachers designing and implementing SEGs in their classrooms. In keeping with the spirit of design-based research described by Barab and Squire (2004), this study focused on ecological validity by asking teacher-participants to craft SEGs that both included relevant content and could be implemented in their classrooms during the study.

The first summer and subsequent four academic-year workshops instructed the participating teachers on how to use game development software and how to create a science- or math-based educational game that aligned with the content standards from the respective grade level and content area.

The second summer and subsequent academic year workshops were designed to help teachers refine their games and integrate the games into their curriculum plans through problem-based learning mechanics. While professional development workshops were delivered by HI FIVES staff, each segment of the professional development was a largely constructivist affair, with mentorship provided by teachers from the previous block of teachers.

Sample

Teachers participating in the workshop were randomly selected from a sampling frame that included the science teachers of nine school districts in a southeastern state, with representation from across the urban-rural continuum, with the final sample consisting of 10% of the total population of teachers in the district. All participants were monetarily compensated, as well as given continuing education credit for their participation in the research project. The final group of teachers (n = 38) was intentionally selected to be polled on the effectiveness of the game development workshops.

As this final group did not have any previous experience with game design, they were less likely to be influenced by prior experiences with SEGs and the previous groups of teachers. Of the 38 teachers selected for analysis, 28 were female and 10 were male. Thirty-two of the 38 teachers taught middle school, 3 taught high school, and 3 had a joint appointment between middle and high school.

Data Collection and Instrumentation/Research Design

A posttest-only design was employed because the goal of the study was to see how the professional development model worked in terms of identifying indicators of TPACK on innovation adoption as it pertained to the six baseline variables. Workshop data were collected on the last day of the first 5-day workshop for this cohort, through a modified version of a survey instrument from the National Science Foundation ITEST project Ocean Explorers (see appendix). The instrument consists of three leading questions with several subquestions and an open response area following each leading question.

The objective set forth by the Ocean Explorers project aligned with the goals of the HI FIVES project, so the only modifications to the instrument included changing the project name and the type of software employed in the study. Additionally, validation of the instrument occurred through project staff and evaluator agreement that responses to the questions in the instrument suggested a teacher's position on the Rogers (2003) Innovation Adoption Curve, comparing frequencies of each scale score within the subscales to the curve itself (see Figure 2) and assigning categories accordingly. In essence, the more favorable a participant's response to the workshop and adoption of technology in their classroom, the closer to innovator we placed them on Roger's (2003) framework. While this strategy assumed that Rogers' distribution percentages are relatively accurate, an interrater reliability of 90% across three independent raters confirmed these categorizations.

Furthermore, teacher demographic data and an additional six categories hypothesized to be indicators of innovation adoption as it pertained to SEG design by teachers were added to the instrument from the baseline data collected upon induction of each teacher participant to the project. These six additional categories included grade level taught, hours of online chatting per day, hours of computer use per day, gender, and number of hours of personal SEGs played per day.

Data Analysis

Teacher survey results were recorded using a 5-point Likert scale (5 = *strongly agree* through 1 = *strongly disagree*). The questions were grouped into three subsets based on the leading questions. Subscale 1 identified teacher perception of how well the workshop was planned and presented, subscale 2 identified teacher perceptions of the opportunities afforded based on their participation in the workshop, and subscale 3 examined teachers' perceived learning from the workshop. Two participants were dropped at this point due to nonresponse to survey items.

Each of the subscales drawn from a leading question was assigned a scale score based upon outputs using the Rasch Model. In brief, employing a Rasch model for scaling linearizes ordinal data using a logit function, resulting in ratio/interval data that can be used for numeric analysis (Fischer & Molenarr, 1995).

In addition to the Likert data collected from the surveys, open-ended questions attached to the end of the response forms yielded qualitative data on participant attitudes toward all three constructs. Responses were coded as positive, neutral, or negative in attitude toward the topics of each subscale. These responses were combined with categorizations based on the survey in order to place participants on Rogers' adoption curve, with greater numbers of positive qualitative responses corresponding to higher scale scores in each subscale.

Results

The raw scores for each subscale were converted to logits using a Rasch model for purposes of analysis; Infit and outfit statistics for all three constructs can be found in Table 1. In brief, infit and outfit statistics for all subscales fell between .8 and 1.2, indicating an acceptable item fit to the construct (Fischer & Molenarr, 1995).

Scale scores developed using the Rasch model were used to conduct ANOVA regressions against the six demographic variables hypothesized to have an impact on adoption of technology and the related perceptions of workshop presentation, opportunity afforded by the workshop, and TPACK learning. Additionally, scale scores from each subscale were regressed against one another for predictive purposes. Results indicate that none of the preselected demographic variables had a significant effect on any of the three scale scores.

Table 1
Rasch Model Fit Statistics by Subscale

Subscale	Infit	Outfit
Workshop Presentation	.99	.95
Opportunities Presented	.98	.83
TPACK Learning	.98	.91

Pearson correlations between subscales were significant at a .05 alpha level, with strong associations present between participants' perceptions of how the workshop was conducted, the opportunities the workshop afforded, and the TPACK learning that occurred during the workshop (Table 2).

Table 2
Associations Between Subscales

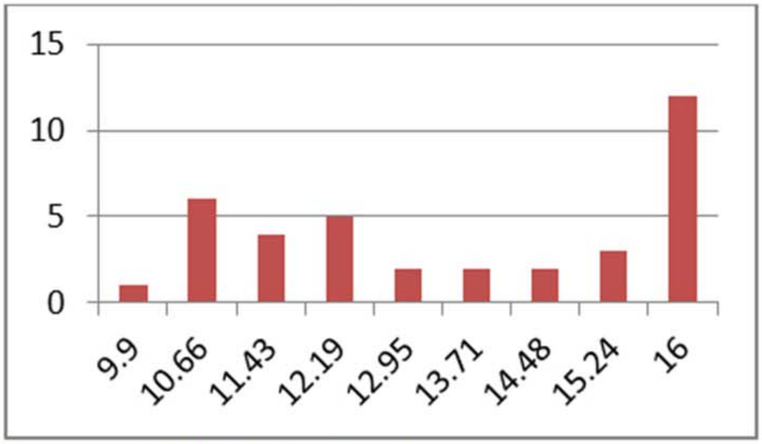
	Workshop Presentation	Opportunities Afforded
Workshop Presentation		$r = .788$, $p < .001$
Opportunities Afforded	$r = .788$, $p < .001$	
TPACK Learning	$r = .645$, $p = .007$	$r = .833$, $p < .001$

Dividing scale scores for all subscales into ranges and pairing them with qualitative responses for each range of scores does illuminate the variations in attitudes toward both the workshop and TPACK that correspond to the adoption curve (Table 3). Each scale demonstrates a multimodal distribution of responses, with a large peak at the upper end of the response continuum, a smaller peak closer to the midpoint, and in the case of the subscales related to TPACK, another small peak lower in the score ranges. (Figure 2).

Table 3
Frequency of Scale Scores by Subscale

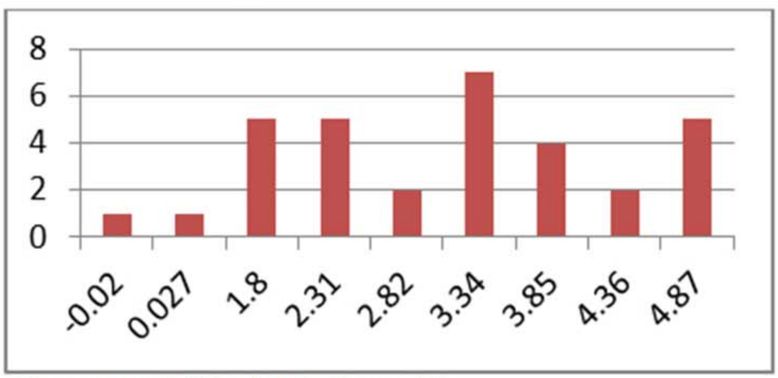
Workshop Presentation	*n*	Opportunities Afforded	*n*	TPACK Learning	*n*
9.90	1	5.90	1	-.02	1
10.66	6	6.68	5	.027	1
11.43	4	7.46	2	1.80	5
12.19	5	8.24	3	2.31	5
12.95	2	9.02	3	2.82	2
13.71	2	9.80	6	3.34	7
14.48	2	10.59	7	3.85	4
15.24	3	11.37	5	4.36	2
16.00	12	12.15	4	4.87	5
				5.38	4

2a. Subscale 1: Workshop Presentation



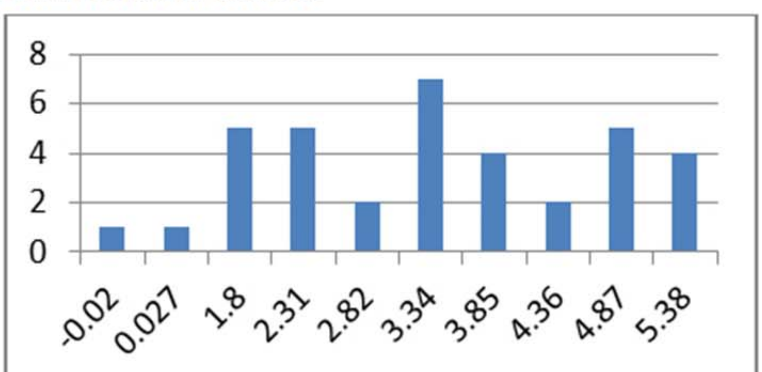
Frequency (y) by Scale Score (x)

2b. Subscale 2: Opportunities Afforded



Frequency (y) by Scale Score (x)

2c. Subscale 3: TPACK



Frequency (y) by Scale Score (x)

Figure 2. *Distribution of scores.*

Discussion

The findings from this study indicated that gender, various exposures to technology, and grade level taught do not have significant effects on the perceptions of participants in a technologically based professional development program for teachers and their potential to adopt innovative technologies into their current pedagogical practices. It should be noted, however, that the group size for gender may not have been sufficient to detect an effect at an alpha level of .05.

In this study, teachers were instructed about how to create their own SEGs that aligned with their respective content standards. As a result of this professional development model, teachers took more ownership of the resources, had higher confidence in integrating the unit as a teaching tool, and were more likely to believe that the curriculum resources would have a positive impact on student achievement. Overall, from the comments provided by the participants and the frequencies of those comments summarized in Table 3, it was concluded that the teacher participants enjoyed the workshop, enjoyed the project staff, and had insight as to how the professional development model could evolve and improve. Most importantly, the strong association between perceptions of the workshop and perceived learning, and perceptions of the workshop and opportunities afforded, suggests that an environment conducive to self-pacing and social interaction may support teachers' desire to adopt new technologies. Additionally, the findings from this study can serve as the framework for professional development of innovative science technologies in subsequent studies.

Adoption of Innovations

The open-ended responses, when paired with frequencies of scale score responses, indicated trends in perceptions that can be matched to Rogers' (2003) adoption curve. Participants scoring in the highest range for TPACK (4.3-5.4), opportunities afforded (9+), and perception of the workshop (>15) produced overwhelmingly positive comments and attributed shortcomings in the professional development to failures of technology and materials rather than to the presenters' actions. Examples of comments in favor of the study include the following:

- "The presenters were very helpful, encouraging, and flexible. It was an enjoyable experience and painless."
- "I was very pleased at the comfortable pace the course was taught. Additionally everyone was very helpful."
- "His is one of the best workshops I have attended."

The following is a telling example of positive outlook on the workshop, in general, and a willingness to overlook difficulties: "Negative feedback due to the fact that this is a new program and some things were beyond anyone's control...next time will be better."

By comparison, those in the less responsive groups, as demonstrated by scale score frequencies (TPACK below 2.5, Opportunities <7, Workshop perceptions <13), indicated some frustrations with the technology or the need for greater assistance with learning to use the software. This is best exemplified by comments such as the following:

- "I would have preferred to have had some of the instruction given to us in written form. Also, a blog would have been nice as a resource for common problems encountered."
- "Could be improved by having a print out of instructions to use, or a blog/forum for commonly asked questions. This would also help while we are trying to work on this by ourselves at home."
- "Improvement of IT skills is an ongoing process."
- "This was very helpful, but I need to practice at home as well and will then hopefully see results."
- "It was incredibly helpful to sit at the table with younger participants who were more savvy in gaming than I."

Analysis of these and other comments indicated that the participant group was split, albeit unevenly, between two groups at the earlier end of Rogers' (2003) scale. Examination of the frequencies of responses compared to the range of potential scale scores would indicate that this group did not consist of innovators, due to the peak responses being below the highest potential scale scores and the first group of the three group cascade being volunteers who were most likely to be technological innovators. Given the frequency of responses in the lowest range of scale scores for subscales 2 and 3 is quite low and the multiple peaks in those subscales, it seems most likely that participants fell into early adopters and the early and late majority categories. The largely positive comments present for participants with the lowest scale scores supports the notion that participants least amenable to adoption do not fit the traditional definition of laggards.

Rogers (2003) defined several intrinsic characteristics of innovations that influence an individual's decision to adopt or reject an innovation. The relative advantage of current science educational SEGs is that they are an improvement over previous educational games like the Oregon Trail® (Rogers, 2003). In order for current educational games to diffuse into mainstream pedagogical practices, they must be compatible with current pedagogies so they can be seamlessly assimilated into the classroom and engage and motivate today's learner. Furthermore, these results indicated that the science game designs were not viewed as extremely complex, which increases the chances for adoption into classroom practice).

The trialability of science educational games in this study showed that the innovation was relatively easy to use with few technical difficulties in software use that might disrupt the innovation's adoption. Finally, while not apparent in the data presented here, this innovation of science educational games has prompted an intense observable interest in both the participants and research staff, which has resulted in more funding to broaden the impact of this innovation.

Additionally, these results suggested a collective type of innovation-decisions process as a method of diffusion and adoption of science games. Communication across the social system has been and continues to be made by the collective group involved in this project. Hence, in this case, the collective-innovation decisions are more powerful than optional or authority innovation-decisions because the social system of professional educators drives the communication rather than a select few. Synthesis of the comments, association between survey subscales, and results indicating that teachers who engaged in online chat were more likely to adopt SEGs indicates that social interaction and a favorable collaborative environment are essential to perceptions of successful implementation of SEGS.

Moreover, this study suggested that the educational game creation software used for the HI FIVES project represented the five phases of technological innovations as suggested by Rogers (2003). Clearly, teacher participants gained knowledge of the innovation, formed a favorable impression, made a decision to commit to the adoption, implemented their game designs into their classrooms, and confirmed the innovation through positive reinforcement and feedback from their students.

Technical difficulties often disrupt adoption of innovations. The software in HI FIVES is not as good in quality as commercial SEGs, but it provided teachers with the ability to create technology that is better than what they currently have available to them in school. This study indicates that a commercial game creation tool that is of the same quality as commercial games yet inexpensive to educators may have the potential to reach engage students with science concepts.

Implications for Practice

There are both positive and negative outcomes when an individual or organization chooses to adopt a particular innovation. Rogers (2003) believed that this area needs further research, because an inherent positive bias is associated with the adoption of a new innovation. A number of studies have used the Diffusion of Innovation Theory in educational settings, many with a focus in instructional technology, although most of them examined relatively commonplace technologies for the time of the studies, such as computer use by instructors (Rogers, 2003; Sahin, 2006).

This study demonstrated the implication of diffusing innovative technologies in science education. Thus, the educational community needs to understand how to diffuse these innovations at a macro level to reform how content is delivered and learned in the 21st-century classroom. The correlations between perceptions of workshop presentation and perceptions of opportunities afforded and TPACK improvement suggest the importance of embedding professional development in an environment that elicits positive responses from participants. In the case of this study, such an environment included the opportunity to work with peers and learner-appropriate pacing.

Perhaps more importantly, the HI FIVES professional development and project as a whole centered around fostering teacher creation of SEGs for implementation in their classrooms, which both afforded opportunity for TPACK improvement and encouraged teachers to embed their current content and pedagogical knowledge within the games they would later implement in their classroom.

Another area to explore as science education begins to adopt innovative technologies at the K-12 level is the work being done at the National Science Resource Center (NSRC). This group has created the Science Education Systemic Reform Model. Available evidence suggests not that technology creates educational improvement but rather that educational improvement comes about through coherent instruction and assessment that supports high-quality student learning.

Technology can remedy boredom created in students by teaching the same things in routine ways. However, decisions about when to use technology, what technology to use, and for what purposes cannot be made in isolation of theories and research on learning, instruction, and assessment (Lawless & Pellegrino, 2007). Components of the Science Education Systemic Reform model (NSRC, 2003) include the following:

1. A curriculum framework and comprehensive research-based K–16 science instructional program based upon research findings.
2. Teachers participating in professional development programs that are aligned with current research about adult learning and designed to move teachers from novice to expertise.
3. Assessments that are aligned with research about how students learn and that elicit meaningful feedback about student learning.
4. Cost-effective and efficient systems that supply resources and materials to teachers.
5. Administrative and community leaders providing long-term support for research-based science learning and teaching.

Limitations

The data analyzed in this study were collected from self-report measures at the end of the workshop, rather than observations of teacher behavior or reports of actual implementation. As such, the results are a more effective measure of attitudes, or intent to adopt, than they are of classroom implementation. Furthermore, the instrument used to determine these results was repurposed, which may limit the validity of its use for this study.

Conclusions

This study addressed the first four components of Rogers' model, with a specific focus on the second component. Additional studies within this project will address the fifth component of the model. Furthermore, future studies will include direct scales of Rogers' adoption framework, several of which have been validated since the study was conducted. The primary emphasis in these future studies will be building and sustaining relationships with school administration and faculty. Professional development focuses on these types of collegial relationships. If teachers feel a sense of comfort, trust, and support in the professional development program, then they are more likely to adopt an innovation.

Further, the National Research Council (NRC, 2011) summarized the research on games, concluding that SEGs and simulations that integrate science processes and clear learning goals increase learners' interest, scientific reasoning, and conceptual understanding; it was also noted that the research linking games to achievement is limited. Computer games and simulations, including SEGs, have a great potential to foster and scaffold inquiry approaches to science teaching and appeal to students through links to technology used in their daily lives (NRC, 2011).

Support of science process skills and inquiry-based instruction also mirror the cross-cutting concepts related to the nature of science in the *Next Generation Science Standards* (NGSS; Achieve Inc., 2013). Initiatives designed to initiate and support teachers' implementation of games and simulations in the science classroom are a plausible means of reaching the goals of both the NRC and the NGSS.

Ultimately, the thrust of these initiatives needs to be geared toward TPACK. While SEGs may be designed to fully integrate content into technology, how they are used in the classroom depends on integration with pedagogical knowledge on the part of teachers, and their self-perceived ability to do so can foster or inhibit initiatives aimed at implementing games and simulations in the classroom. As a stand-alone method, SEGs typically incorporate technology and content knowledge. However, well-designed SEGs, for example the physics game created by Clark and colleagues (2011), may also incorporate pedagogical tools like scaffolding in-game.

The integration of SEGs with appropriate pedagogy is left to the classroom teacher. Effectively integrating technology into a science classroom that is based on strong research and content will create better opportunities for students to succeed in science, technology, and mathematics education and create a new generation of innovators.

References

Achieve, Inc. (2013). *The next generation science standards.* Retrieved from http://www.nextgenscience.org

Annetta, L.A. (2008). Video games in education: Why they should be used and how they are being used. *Theory Into Practice, 47*, 229-239. doi: 10.1080/00405840802153940

Annetta, L.A., & Matus, J.C. (2004). Analysis of satisfaction and perceived learning of science in different distance education delivery modes for rural elementary school teachers involved in a professional development project. *International Journal of Science and Mathematics Education 1*(3), 311-331. doi: 10.1023/B:IJMA.0000039912.97092.4b

Barab, S. A., MaKinster, J.G., & Scheckler, R. (2004). Designing system dualities: Characterizing online community. In S. A. Barab, R. Kling & J. Gray (Ed.), *Designing for virtual communities in the service of learning*. Cambridge, UK: Cambridge University Press. doi: 10.1017/cbo9780511805080

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences, 13*(1), 1-14. doi:10.1207/s15327809jls1301_1

Becker, K. (2007). Digital game-based learning once removed: Teaching teachers. *British Journal of Educational Technology, 38*(3), 478-488. doi: 10.1111/j.1467-8535.2009.0150.x

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Sciences, 2*(2), 141-178. doi: 10.127/s15327809jls0202_2

CELT. (1997). Information on the WIPK-12. Wisconsin educational technology plan PK-12: Executive summary and recommendations. Retrieved from http://imt.dpi.wi.gov/imt_digital-learning-plan-update-spring-2014

CEO Forum. (2000, June). *The power of digital learning: Integrating digital content (Year 3 Report)*. Washington, DC: CEO Forum on Education and Technology.

Christensen, C. M., & Horn, M.B. (2008). How do we transform our schools? Use technologies that compete against nothing. *Education Next, 8*(3), 13-19. Retrieved from www.educationnext.org

Clark, D. B., Nelson, B. C., Chang, H., Martinez-Garza, M., Slack, K., & D'Angelo, C. M. (2011). Exploring Newtonian mechanics in a conceptually-integrated digital game: Comparison of learning and affective outcomes for students in Taiwan and the United States. *Computers & Education, 57*(3), 2178-2195. doi: 10.1016/j.compedu.2011.05.007.

Cook, M.D. (2008). Problem-based learning as the backbone for educational game design. In L.A. Annetta (Ed.), *Serious educational games: From theory to practice* (pp. 57-64). Amsterdam, The Netherlands: Sense Publishers. doi: 10.1080/00405840802153940

Dori, Y. J., & Barnea, N. (1994, March). *In-service chemistry teachers training: The impact of introducing computer technology on teachers' attitudes.* Paper presented at the National Association for Research in Science Teaching, Anaheim, CA.

Dewey, J. (1916). *Democracy and education*. New York, NY: Free Press.

Electronic Software Association. (2013). *2013 sales, demographics and usage data: Essential facts about the computer and video game industry*. Retrieved from http://www.theesa.com/facts/pdfs/esa_ef_2013.pdf

Fischer, G.H., & Molenarr , I.M.(1995). *Rasch models: Foundations, recent developments and applications.* New York, NY: Springer. doi: 10.1007/978-1-4612-4230-7

Friedman, T. L. (2005). *The world is flat: A brief history of the twenty-first century*. New York, NY: Farrar, Straus, and Giroux.

Goldman, H. (2013, June 4). Momentum continues: Ed tech legislation introduced in the senate [Web log post]. Retrieved from the ISTE Connects Blog: http://blog.iste.org/momentum-continues-ed-tech-legislation-introduced-senate/

Lawless, K. A., & Pellegrino, J.W. (2007). Professional development integrating technology into teaching and learning: Knowns, unknowns, and ways to pursue better questions and answers. *Review of Educational Research, 77*(4), 575-614. doi: 10.1111/j.1744-7984.2007.00115.x

Loucks-Horsley, S., Stiles, K.E., Mundry, S., Love, N., & Hewson, P.W. (2010). *Designing professional development for teachers of science and mathematics* (3rd ed.). Thousand Oaks, CA: Corwin.

Mishra, P., & Koehler, M.J. (2006). Technological pedagogical content knowledge: A new framework for teacher knowledge. *Teachers College Record, 108*(6), 1017-1054. *doi:* 10.1111/j.1467-9620.2006.00684.x

National Science Resource Center. (2003). Theory of action. Retrieved from the Carolina Biological Supply Company website: http://www.carolinacurriculum.com/stc/pdfs/STC_Global/NSRC_overview.pdf

National Research Council. (2011). *Learning science through computer games and simulations.* Washington, DC: National Academies Press.

Niess, M. L., van Zee, E. H., & Gillow-Wiles, H. (2011). Knowledge growth in teaching mathematics/science with spreadsheets: Moving PCK to TPACK through online professional development. *Journal of Digital Learning in Teacher Education*, *27*(2), 42-52. doi: 10.1080/21532974.2010.10784657

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York, NY: Free Press.

Sabelli, N. (2006). Complexity, technology, science and education. *Journal of Learning Sciences, 15*(1), 5-9. doi: 10.1207/s15327809jls1501_3

Sahin, I. (2006). Detailed review of Rogers' Diffusion of Innovations theory and educational-technology-related studies based on Rogers' theory. *The Turkish Online Journal of Educational Technology*, *5*(2). Retrieved from http://www.tojet.net/articles/v5i2/523.pdf

Sprague, D. (2004). Technology and teacher education: Are we talking to ourselves. *Contemporary Issues in Technology and Teacher Education 3*(4), 353-361. Retrieved from http://www.citejournal.org/vol3/iss4/editorial/article1.cfm

Stansbury, M. (2008). Students want more use of gaming technology. *eSchoolNews*. Retrieved from http://www.eschoolnews.com/2008/04/08/students-want-more-use-of-gaming-technology/

Stevens, P., & Weale, M. (2003). *Education and economic growth*. Retrieved from the Centre for the Economics of Education website: http://cee.lse.ac.uk/conference_papers/28_11_2003/martin_weale.pdf

Task Force on the Future of American Innovation. (2005). The knowledge economy: Is the United States losing its competitive edge? (Benchmarks of Our Innovation Future) Retrieved from the Perkins Collaborative Resource Network website: http://cte.ed.gov/nationalinitiatives/gandctools_viewfile.cfm?d=600189

Zigmarmi, P., Betz, L., & Jennings, D. (1977). Teachers' preferences in and perceptions of inservice. *Educational Leadership, 34*(7),545-551.

Author Notes

This material is based upon work supported by the National Science Foundation under ITEST Grant No. 0525115. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Appendix

1. How would you rate this workshop in terms of the following:

Q1a	a. Participants were introduced to specific learning objectives
Q1b	b. Clear instructions were given during activities
Q1c	c. Materials, supplies and equipment were ready as needed
Q1d	d. The content of the workshop reflected planning and organization
Q1e	e. The presenter(s) was/were well prepared
Q1f	f. The workshop was conducted at a comfortable pace
Q1g	g. Questions and concerns were handled by the presenter(s) appropriately
Q1h	h. The presenter(s) provided for a variety of learning styles
Q1i	i. The experiences of participants were utilized as a resource for learning
Q1j	j. Participants were provided with feedback and encouragement
Q1Comment	Comment

2. How would you rate this workshop in terms of the following:

Q2a	a. Opportunity to improve my IT skills
Q2b	b. Opportunity to improve my IT knowledge
Q2c	c. Opportunity to network with people with similar interests
Q2d	d. Opportunity to be a part of a professional community
Q2e	e. Desirability of workshop location
Q2Comment	Comment

3. In this workshop, to what extent have you:

Q3a	a. Learned how SEGs can be used to learn about science
Q3b	b. Become familiar with SEGs to teach science lessons
Q3c	c. Learned how SEGs deals with rich narratives
Q3d	d. Become familiar with the V software
Q3e	e. Learned how to modify a problem-based activity
Q3f	f. Learned how to design and create storyboards
Q3g	g. Learned how to change the environment o by adding a new character or object
Q3h	h. Learned how to add behaviors or characters and objects
Q3i	i. Learned how to add embedded assessments into the game