# Chapter 5

## *Discussion*

This chapter begins with a brief overview of the study and the results, followed by a discussion of a participant's perceptions of the innovation and their effect on her micro-adoption decision. I will discuss how participants' uses of the RepliGo™ digital annotation software contribute to the research on formative assessments of reading comprehension. I then discuss the revisions to the IAP model, instruments, and protocols in light of the results and how the methodology of the IAP contributes to the development of cognitively-oriented technology innovations and the practice of school leadership. The chapter concludes with the methodological contributions of the study to diffusion of innovations research, the limitations of the study, and directions for future research.

### *Overview of the Study and the Results*

This study examined the ability of diffusion of innovations (DOI) theory, as embodied in the Innovation Adoption Profile (IAP), to indicate teachers' decisions to participate in the field trial of a software innovation and to implement the innovation. The IAP is comprised of 15 factors drawn from the prior conditions (i.e., innovativeness) and persuasion stage (i.e., the perceived characteristics of the innovation) of Rogers' (2003) innovation-decision process model as illustrated in Figure 1 in Chapter 1. This examination of the IAP was performed in a K-12 school district using an authentic innovation (RepliGo™) and a two-phase point-of-adoption design that collected data immediately before and after participants made their adoption decision (Meyer, 2004; Rogers, 2003).

The results of the Phase 1 data analysis indicated that two factors emerged in the smaller IAP model as significant indicators of participants' decision to participate in the field trial of RepliGo™: the perceived characteristics of the innovation (PCIs) called *compatibility with current work practice*, and *relative advantage*. A third PCI, *trialability*, emerged as marginally significant in the smaller IAP model. The interview data adequately triangulated the survey data analysis and results and more fully described participants' reasons for making their field trial participation choice. The Phase 1 findings supported the established importance of *relative advantage* and *compatibility* as primary factors in determining the adoption decision (Carter & Belanger, 2003; Jebeile & Reeve, 2003; Karahanna, Straub, & Chervany, 1999; Rogers, 2003).

The results of the Phase 2 data analysis indicated how the two teachers, Richard and Julia, used RepliGo™ in their classrooms. Richard and Julia's uses of RepliGo™ were analyzed using the RAT taxonomy (Hughes, 2000) to describe the level of change their usage produced in their classrooms. Both teachers used RepliGo™ in ways that amplified their instructional practice, and Richard used RepliGo™ to transform his vocabulary assessments. The RAT analysis was found to be a deep usage measure that is superior to the shallow usage measures (i.e., frequency, duration) employed in the majority of DOI research (Chin & Marcolin, 2001; Meyer, 2004; Rogers, 2003). The analysis of the PCIs in the Phase 2 data identified the important indicators of Richard and Julia's usage of RepliGo™: *relative advantage*, *compatibility*, and *ease of use*. This finding supported the established importance of these PCIs, not only in the decision to adopt an innovation, but also in indicating their near-term use (Karahanna, Straub, & Chervany, 1999; Tornatzky & Klein, 1982).

*The Effect of Participant Perceptions on Micro-Adoption Decisions*

In this section I discuss Julia's rejection of RepliGo™ after one day of use in her classroom. Implications of her rejection are connected to the literature on the effects of high stakes tests and teachers' technology adoptions.

The results of Phase 1 and Phase 2 of this study appear on their surface as straightforward confirmation of factors identified in other studies using the dominant DOI research methodology (i.e., quantitative methods used to examine a diffused innovation with adopters as the data source) However, the IAP methodology (qualitative and quantitative methods used to examine an innovation before and after adoption with adopters and rejecters as the data source) revealed in one case the power of a single PCI construct to drive a teacher's adoption decision making. Julia's rejection of RepliGo™ after adopting it, a behavior Rogers (2003) calls *discontinuance*, is a special case that illustrates the power of a single PCI.

The PCI construct *compatibility* played a role in both Julia's adoption and discontinuance. Specifically, it was Julia's perceptions of RepliGo™'s compatibility with her goal to help her students pass the state-mandated reading assessment that indicated *both* her adoption *and* discontinuance. During her RepliGo™ workshop in late April of 2005, Julia's PCIS means for compatibility with current work practice and compatibility with preferred work style indicated the highest possible level of agreement with those scale items. This meant that Julia believed RepliGo™ was compatible with the way she was working and the way she wanted to work. During her follow-up interview Julia was clear that using RepliGo™ would help her students prepare for the state-mandated reading assessment. However, three events in the timeline leading up to her micro-adoption decision and her subsequent use of RepliGo™ combined to reverse her perceptions of RepliGo™ and move her from adoption into discontinuance. The first event was the timing of her late April workshop just two weeks after her students had completed the state-mandated reading assessment for the 2004-2005 school year. In essence, the pressure of the state-mandated assessment was reduced, and she was free to consider the innovation. Second, Julia did not have the chance to begin using RepliGo™ with her students until six weeks into the 2005-2006 school year. Third, the state-mandated reading assessment was moved earlier from mid-April to mid-January, 2006. Thus, instead of being able to implement RepliGo™ during a period *after* her students had completed the state-mandated reading assessment, Julia was implementing RepliGo™ less than three months *before* the state-mandated reading assessment.

The pressure on Julia to have her students pass the statewide mandated reading assessment was acute because her students had already failed the assessment once. She described this pressure during her final Phase 2 interview, stating she needed to use multiple-choice assessments instead of RepliGo™ because the statewide mandated reading assessment was primarily a multiple-choice assessment. Thus, the statewide reading assessment impacted Julia's adoption and discontinuance of RepliGo™ as a formative assessment. Julia's discontinuance of RepliGo™ supports Boardman and Woodruff's (2004) finding that "teaching in a 'high-stakes' assessment environment impacts the implementation, fidelity, and sustainability of new teaching methods" (p. 545). As stated earlier, it was Julia's initial perception of RepliGo™ as compatible with the goals of her class that was her principal reason for her participation in the field trial. However, her perceptions of RepliGo™ changed when she compared the kind of formative assessment possible with RepliGo™ against her perceived need to use multiple-choice items as formative assessments. When Julia was making the comparison between using RepliGo™ and multiple-choice assessments, she may have been acting as Boardman and Woodruff described when they concluded "that some teachers may use 'high-stakes' assessments as their primary reference point in which to gauge the merit of innovative teaching practices" (p. 545). While Boardman and Woodruff (2004) examined the effects of high stakes assessments on the implementation of innovative teaching practices in general, Frank, Zhao, and Borman (2004) included a school's emphasis on standardized testing as a factor affecting teachers' technology adoptions. Frank, Zhao, and Borman categorized standardized testing within their "job stress" category and noted "job stress can demand immediate resources, distract attention, and induce burnout, all of which may affect an individual's capacity and intent to implement innovations" (p. 157). Thus, Julia's discontinuance of using RepliGo™ is another example of the effects of high stakes assessments on teachers and, hence, their students. Looking at Julia's discontinuance from the perspective of DOI theory, it is apparent that digital annotation is incompatible with the multiple-choice testing Julia felt compelled to use in her classroom, thereby teachers implementing technology innovations must be given the opportunity to implement them in conditions where their practice is not so tightly constrained by accountability measures.

*Participants' Uses Of Repligo™ Digital Annotation Software*

In this section, I discuss how Richard and Julia's uses of the RepliGo™ digital annotation software contribute to the research on the formative assessment of reading comprehension. Three arguments for the expansion of research into digital annotation as a formative assessment are made, and four areas for future research are suggested.

Three fundamental arguments emerged from this study for expanding research into students' annotations as formative assessments of reading comprehension. First, annotation is an activity students do while reading, or as Snow (2002) stated, performing "operations to process the text at hand" (p. 15). Thus, using annotations as formative assessments brings the assessment closer to what Pearson (2005) calls the "'click' of comprehension" (slide 54), the moment when the student understands (or does not understand) the text. Using annotation reduces the teacher's reliance on artifacts such as accounts of whether the student understood, what they understood, or quizzes on what they remembered (slide 6). When Richard asked his students to highlight the words they did not know through annotation, he was substituting annotation practices for a quiz on what they understood. Richard stopped *asking* students to remember what they knew and began *seeing* what they did and did not know at the moment they encountered difficulty. Thus, digital annotation is an assessment that is delivered *while* students process the text, close to Pearson's "'click' of comprehension," not at some later point in time. Thereby digital annotation is a formative assessment closer to the moment of comprehension than other available assessments.

Second, students' annotations should be used as formative assessments because annotations constitute a metacognitive trace (Winne & Hadwin, 1998) left behind by the student as they read. For example, Julia asked her students to use RepliGo™ to demonstrate their ability to have a purpose while reading. As students read and annotated the passage describing a house and its contents, students monitored their thinking in order to notice when they shifted their purpose in reading among the three purposes the assignment demanded they use (i.e., the student's own purpose, the purpose of a thief, the purpose of a real estate agent). Thus, each time they annotated the text using a different highlight color for each purpose, they left behind a trace of the shift in their thinking. Winne and Hadwin called this activity "traces of study tactics" (p. 280) and recommended students' annotations as evidence for student learning. Thus, Julia was using her student's annotations as traces that documented their awareness of their learning. Thereby digital annotation is a visible trace of students' metacognition.

Third, annotation meets the standard for a useful assessment system for reading comprehension. Snow (2002) states that at a minimum, a reading comprehension assessment must demonstrate four strengths. It must: (a) be congruent with the processes involved in comprehension, (b) target operations involved in reading comprehension, (c) provide information useful for instructional decision making, and (d) provide transparent information (i.e., information useful to teachers with little technical training in assessment). Richard's use of RepliGo™ demonstrated these four strengths in that (a) students completed the assessment while reading, (b) students demonstrated they did or did not understand the vocabulary, (c) students provided information in their annotations that altered Richard's instructional method, and (d) Richard gathered this information after less than two hours of training. Thus, even though Richard's use of RepliGo™ as a formative assessment was simple, it was effective and met Snow's test for a useful assessment system.

The three arguments for expanding research into students' annotations as formative assessments pertain to *annotation.* However, it is the *digital* aspects of a digital annotation system that makes students' annotations practical formative assessments. In *Knowing What Students Know* (National Research Council, 2001), the authors include a chapter on the uses of information technologies to advance educational assessment. They conclude that information technologies remove constraints on assessment practice, extend "the knowledge and cognitive processes that can be assessed" (p. 288), and facilitate the embedding of assessment in instructional settings. RepliGo™, and digital annotation systems in general, remove two significant constraints: (a) the prohibition against annotating in paper textbooks, and (b) the inherent impracticality associated with sharing annotations made on paper materials. When Richard observed words his students were highlighting, he was assessing a different cognitive process than when his students completed a multiple-choice vocabulary quiz, thereby extending the cognitive processes he was assessing. Before using RepliGo™, the cognitive process Richard was assessing when he used multiple-choice vocabulary quizzes was *supported recall* (i.e., students could study in advance and use the responses of the multiple-choice item as scaffolds to think through to the correct response). The cognitive process Richard was assessing when he was using RepliGo™ was *understanding a word in context*. Thus he extended the cognitive process from an inauthentic process (i.e., the multiple-choice vocabulary quiz) to an authentic process (i.e., reading a passage of text). Finally, Richard embedded the assessment in his instruction, using the information students provided him to help them *during* the lesson. Thus, Richard leveraged the digital aspects of RepliGo™ to advance his assessment practice, which then immediately transformed his instruction.

Richard's and Julia's uses of RepliGo™ constitute preliminary evidence that students' annotations are useful formative assessments of reading comprehension. While simple, the kinds of annotations Richard and Julia asked students to do were effective because the students' annotations provided Richard and Julia with information they could use to alter their teaching and help their students learn. However, the use of annotation for formative assessment is not limited to the ways Richard and Julia created during the field trial of RepliGo™ (i.e., identifying unknown words, demonstrating having a purpose while reading). For example, Lick and Lebow (2003, 2003b) described their Collaborative Annotation Model (CAM) and the Hylighter™ digital annotation system they created to enable teachers and students to collaboratively annotate an instructor-assigned reading. CAM is a five-step process whereby students are taught to annotate using techniques such as "question-generation and answer-elaboration…, student-generated elaborations of important points in the text, or…identify and comment on claims, supports, and logical fallacies" (p. 4). The techniques Lick and Lebow mentioned are more sophisticated than those generated by Richard and Julia and, when combined with Richard and Julia's, indicate a range of reading comprehension strategies that can be formatively assessed using students' annotations. However, the data provided by Richard, Julia, and the instructor in Lick and Lebow's study are merely a tentative beginning to the research needed to develop digital annotation as a viable tool for the formative assessment of reading comprehension. Thus, four areas are suggested for future research into the uses of digital annotation as formative assessments of reading comprehension. These are research into (a) the effectiveness of digital annotation as a formative assessment of reading comprehension, (b) the kinds of formative assessments that digital annotation systems can support, (c) how students learn to annotate and teachers learn to use their students' annotations as formative assessments, and (d) the conditions that must be in place so digital annotation can be used as a formative assessment.

*Revisions to the IAP Model, Instruments, and Protocols*

This section describes the revisions to the IAP model, instruments, and protocols in light of the results of the study. Refinements to the dependent variable and the statistical analysis are also presented.

*The revised IAP model.* The Innovation Adoption Profile (IAP) model came under significant revision in light of the data analysis, and the revised version appears in Figure 10. Of the indicators in the original IAP model, the demographic proxies for innovativeness (i.e., age, educational attainment, career moves) are removed, and individual innovativeness and perceived organizational innovativeness are reconfigured as contextual factors for the indicated PCIs. Reconfiguring the two innovativeness constructs into contextual factors rather than direct indicators of adoption reflects the results of the analysis and fits more closely with Rogers' conception of innovativeness as a prior condition within his innovation-decision model as shown in Figure 1 in Chapter 1. Thus, as a prior condition innovativeness is not as likely to play as direct a role in the persuasion stage of the innovation-decision model as the PCIs, and this is reflected in the revised IAP model (Figure 10). Prior experience with technology is added as a contextual factor in this revision of the IAP, but future investigations may prompt a change in the conception of this factor (i.e., prior experience may become a direct factor, remain as a contextual factor, or be removed from the model).

The 10 PCIs used as indicators of teachers' micro adoption decisions will be retained without revision because, according to Rogers (2003), each innovation has its own set of PCIs that potential adopters consider during the persuasion stage of the innovation-decision model. This conception of the PCIs is borne out in the growth and development of the PCIs over time as shown in Figure 6 in Chapter 3. Hence, the IAP is *not* intended to finally determine the correct PCIs for all technology innovations that teachers could ever consider. Rather, the IAP is a model intended to detect *which* PCIs are important indicators of the potential for micro-adoption within specific populations of teachers considering a specific technology innovation. Researchers and school leaders can then use the information provided by the IAP when planning diffusion efforts or making macro-adoption decisions.

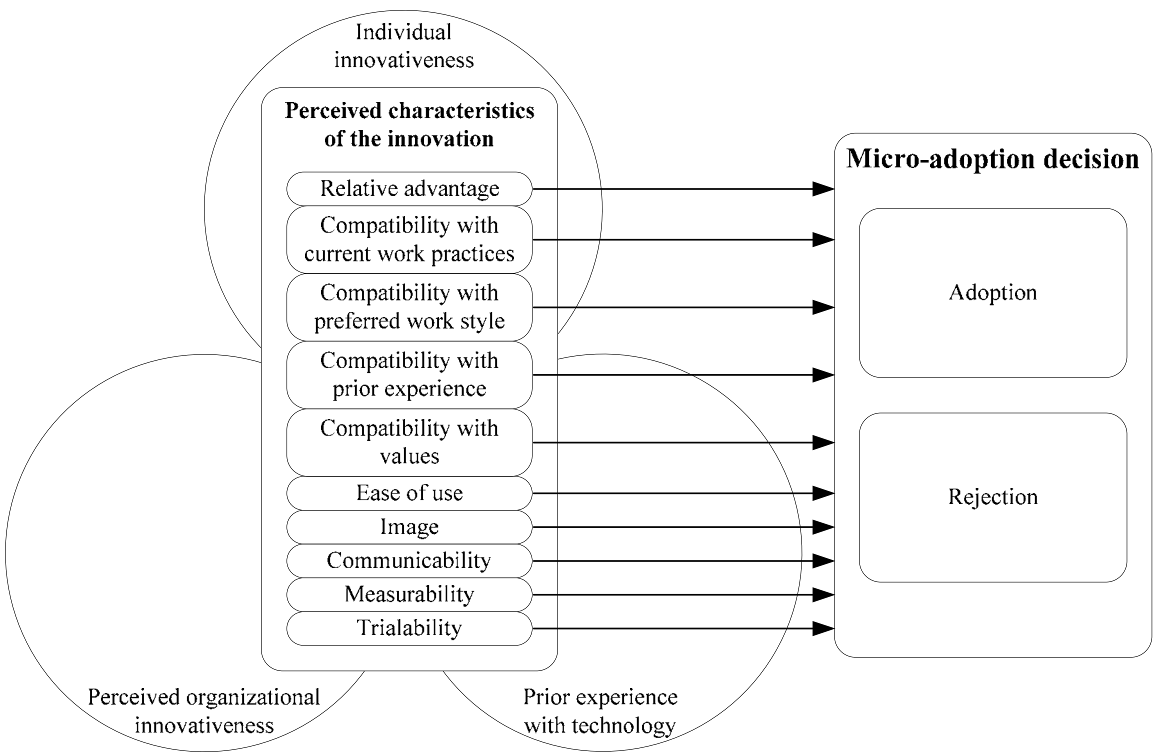


*Figure 10.* Revised Innovation Adoption Profile (IAP) model.

*Revisions to the IAP instruments and protocols.* The survey instruments that measure the constructs in the IAP will be revised to reflect the revisions to the model.

The demographic questions will be eliminated due to the removal of the demographic proxies for innovativeness from the IAP model, and the short form of the Innovativeness Scale (IS) (Hurt, Joseph, & Cook, 1977) will be substituted for the full IS as it has shown sufficient reliability (Hurt, Joseph, & Cook, 1977; Simonson, 2000) and would take less time to complete. Although the results of the administration of the Perceived Organizational Innovativeness Scale (PORGI) (Hurt & Teigen, 1977) in this study were not correlated with participants' field trial adoption choice, the school district in this study was extraordinarily innovative. Thus, it is possible that the perceived organizational construct will be correlated with innovation adoption in another setting so the PORGI will be retained. Future versions of the Perceived Characteristics of Innovating Scale (PCIS) (D. R. Compeau & Meister, 2003) will continue to be customized to the innovation of interest for the particular application of the IAP. In regards to the IAP research protocol, since the innovativeness constructs are now contextual rather than direct indicators of micro-adoption, the IS and PORGI would not have to be administered during the workshop. Administering the IS and PORGI at some other time would either decrease the time needed for the workshop or increase the amount of time teachers would have to experience the innovation during the workshop.

As a further refinement, attention to the dependent variable is important to reflect the type of adoption under consideration. For example, asking teachers to respond to an invitation to participate in a field trial of an innovation that has already been macro-adopted may be perceived as inauthentic. In these cases, using an intention-to-adopt scale (Brown, Massey, Montoya-Weiss, & Burkman, 2002; Chin & Marcolin, 1995; Plouffe, Hulland, & Vandenbosch, 2001) may be advantageous because these scales are designed to capture respondents' intention to use an innovation when rejecting the innovation outright is not an option. Intention-to-adopt scales usually consist of three or four seven-point Likert scale items (i.e., strongly disagree to strongly agree) that collect respondents' intentions to continue using the innovation after their initial experience (i.e., a workshop or field trial). A mean is then calculated and used as the dependent variable in the statistical analysis.

The logistic regression analysis of the Phase 1 data identified the indicators of participants' participation in the field trial of RepliGo™. However, the sample size requirement of logistic regression analysis (i.e., 10-20 cases per independent variable) places demands on future IAP users to obtain minimum sample sizes of at least 100 to produce stable results using the full IAP model. As the IAP is envisioned as a tool usable by both researchers and practitioners, sample sizes of 100 or larger should not be assumed. Thereby, alternatives to logistic regression analysis will be examined to analyze data from small samples without reliance on factor reduction as performed in this study. Additionally, any change in the construction of the dependent variable response from the dichotomous (i.e., yes/no) response used in this study requires a corresponding change in the statistical analysis. For example, an intention-to-adopt scale would require an ordinal logistic regression analysis.

The follow-up interview protocol was found to be an effective elicitor of the PCIs participants felt were important and will be retained unchanged. However, email and voicemail versions of the follow-up interview will be dropped in favor of face-to-face or telephone interviews due to the higher quality of data obtained. In addition, because of the need to complete follow-up interviews within a short time after the introductory workshop, whenever possible, additional resources will be brought to bear to interview all workshop participants as opposed to a convenience sample as used in this study. Additionally, if the infrastructure is in place, the follow-up interview possibly could be conducted using an online chat technology as suggested by Davis, Bolding, Hart, Sherr, and Elford (2004).

The Phase 2 deep usage protocol will be expanded to include questions explicitly connected to the PCIs. This will address the concerns of the coders that the deep usage data were not sufficiently detailed to consistently explicate the PCIs. Chiasson and Lovato's (2001) case study of an individual user of a decision-support software product will serve as a model for the questions to add to the deep usage protocol.

Finally, a measure of prior experience with technology will be incorporated into the IAP to determine if prior experience with technology is a primary indicator of adoption, a prior condition similar to innovativeness, or an uncorrelated indicator. Compeau and Higgins' (1995) instrument is a possible candidate for a self-efficacy measure, and Marcinkiewicz and Welliver's (1993) or Moersch's (1995) instruments are candidates for a measure of teacher experience with integrating technology into classroom practice.

*Methodological Contributions of the IAP to the Development of Cognitively-Oriented Technology Innovations and School Leadership*

In this section I discuss how the methodology of the IAP contributes to the development of cognitively-oriented technology innovations and the practice of school leadership. Specific examples of how the IAP can be used by both groups are presented.

*Contributions to the development of cognitively-oriented technology innovations.* Fishman, Marx, Blumenfeld, Krajcik, and Soloway (2004) describe a problem in learning technology research: cognitively-oriented technology innovations (COTIs) have not become widespread in K-12 schools. Diffusion of innovation theorists would argue that COTIs are non-diffused innovations. Fishman et al. are not content with the non-diffusion of COTIs and indicate the problem is significant, stating the lack of diffusion of COTIs has "important implications for both the continued viability of research on technologies for learning and on the future of technology use in schools" (p. 46). The source of the non-diffusion of COTIs, according to Fishman et al., is "that most design-based research does not explicitly address systemic issues of usability, scalability, and sustainability," and they conclude that "this limitation must be overcome if research is to create usable knowledge that addresses the challenges confronting technology innovations when implemented in real-world school contexts" (p. 46). Fishman et al. go on to offer an extensive research agenda targeting gaps between the capabilities of school districts to adopt COTIs and the demands COTIs place on school districts. While the bulk of Fishman et al.'s research agenda calls for research into building school district capacity to adopt COTIs, they acknowledge the necessity of approaching the problem as "a two-way street," saying "it is as critical for us, as researchers, to learn how to adjust our demands of our cognitively oriented [sic] technology innovations as it is for school organizations to embark upon changes to meet innovations' demands" (p. 65). In this section I argue DOI theory, as embodied in the IAP methodology, can make a contribution to the problem of non-diffusion of COTIs in school districts. In particular, I argue the IAP will assist those researchers who intend to widely diffuse their COTIs by helping them adapt their COTI designs for widespread diffusion. Thus, the IAP merits further development through inclusion in the research agenda to address the problem of the non-diffusion of COTIs. First, COTIs are described and differences between COTIs and RepliGo™, the innovation used in the study, are explained. Then design-based research, the branch of learning technology research responsible for the development of COTIs, is described and critiqued from a DOI perspective. Finally, the specific contributions of the IAP to the problem of non-diffusion of COTIs are illustrated and suggestions are made for the integration of the IAP methodology into design-based research.

Cognitively-oriented technology innovations (COTIs) are developed with the intention of fostering deep thinking and learning by students. Fishman et al. (2004) describe COTIs use of technology "as a tool to support teaching and learning, as opposed to the object of learning," and COTIs "often use technology to scaffold teaching and learning practices that would be difficult to achieve otherwise" (p. 46). COTIs are grounded in constructivist learning theories, and their implementation includes curriculum materials and new ways for teachers to teach and students to learn. DOI theorists would argue that a COTI is a *technology cluster*, or a package of innovations (i.e., hardware, software, curriculum, learning goals, etc.) that must be adopted together to achieve the intended outcome.

While RepliGo™ is a non-diffused technology innovation among K-12 schools, it is not a COTI. COTIs are designed to embody constructivist learning principles and foster deep thinking. RepliGo™ is designed to meet the needs of businesses intending to distribute documents over mobile networks (i.e., cell phones). Even though RepliGo™ was used by Richard and Julia "as a tool to support teaching and learning" and it made possible assessments “that would have been difficult to achieve otherwise” (Fishman et al., 2004, p. 46), RepliGo™ was not designed with an intention to foster deep thinking and learning by students. Also, while using RepliGo™ did change Richard’s and Julia’s teaching practice, teachers in the Phase 1 field trial were explicitly informed there was no requirement to change their teaching practice in order to adopt RepliGo™.

Additionally, Phase 1 participants were informed they had complete discretion to use RepliGo™ as they saw best. The amount of control teachers were given over how to use RepliGo™ in their classrooms stands in contrast to the conception of a COTI as evidenced by Fishman et al.’s (2004) statement that researchers “must create flexibility in their innovations to allow for mutual adaptation that *preserves core principles*” (p. 66, emphasis added). This means that researchers strive to have COTI-using teachers alter their practice in some way such that the principles of teaching and learning embodied in the COTI are preserved. RepliGo™ embodied no such principles. RepliGo™, in terms of DOI theory, is also a *smaller* innovation than the majority of COTIs. When teachers examined RepliGo™ in their workshops, they only saw a piece of software they could use as they saw fit (i.e. no additional hardware, software, Internet connections, curriculum materials, etc.). In fact, both RepliGo™ and the school district where this study was conducted were chosen to keep the innovation as small as possible (i.e., teachers and students all had laptops and no Internet connection is required to use RepliGo™). When teachers examine a COTI, they see a whole new approach to teach content and engage their students in learning that often includes a host of hardware, software, and learning materials.

Fishman et al. (2004) acknowledged that the non-diffusion of COTIs is intertwined with the methodology design-based researchers employ when creating them. Fishman et al.'s description of their methodology is summarized as follows. When a COTI is under development, design-based researchers typically work inside small numbers (i.e., 1-10) of K-12 classrooms gathering quantitative and qualitative data to inform the design of the COTI. They forge a close relationship with the teachers to support their use of the COTI and sometimes even co-teach lessons. The close relationship among teachers, students, and design-based researchers ideally involves teachers and students as co-developers of the COTI. Thus, while differences between COTIs and RepliGo™ exist, I argue it is the acknowledged features of the research methodology used to create COTIs that are, in part, responsible for the non-diffusion of COTIs.

Three features of design-based research methodology are intertwined with the non-diffusion of COTIs. First, designed-based research, by its very nature, creates a highly supportive environment for the individual teacher involved as a COTI co-developer. Researchers make regular contact with the teacher, technology support provided by research staff is readily available, and extensive teacher professional development is often included as part of the COTI development project. All of this support is vitally important to COTI development as it would be much more difficult to design a COTI without early, frequent, and rich contact with the teachers and students who represent the COTI's intended users. However, Fishman et al. (2004) note "if the conditions depend heavily upon an infusion of extra support from researchers, this may pose a challenge to scalability and sustainability" (p. 47). Examining the supportive environment created by design-based research methodology through the lens of DOI theory, when teachers are provided with extra support from researchers, I argue the *ease of use* of the COTI is artificially lowered. An artificially lowered ease of use means design-based researchers know little about the technology support and professional development demands their COTI would make on adopting school districts. This could lead to design-based researchers' overly optimistic appraisals of school districts' adoption capabilities and hence disappointment when school districts reject the COTI because the districts perceived it as difficult to use.

Second, the attributes of the K-12 classroom teachers who co-develop COTIs alongside the researchers are intertwined with the non-diffusion of COTIs. Fishman et al. (2004) quote Means' (1998) description of these teachers as likely to "buy-in to the philosophy of the project and see the connection of the technology used in the project to something they want to do with their students" (Means, 1998, p. 7). From the perspective of DOI theory, Means (and Fishman et al.) understates the diffusion problem associated with these teacher co-developers. According to the definitions of the adopter categories in Rogers (2003), these teachers are most likely *innovators*. Innovators, as described by Rogers, are individuals who (a) are cosmopolitan, building relationships outside the social network of their peers (i.e., work with university-based learning technology researchers), (b) are able to cope with a high degree of uncertainty about an innovation at the time of adoption (i.e., agree to implement an unfinished innovation in their classroom, (c) are venturesome almost to the point of "obsession" (i.e., participate in a competitive selection process in order to work with design-based researchers), and (d) look to import innovations from outside the boundaries of their current peer network (i.e., knowingly choose to use an untried innovation on their students). Innovators are also rare. Rogers' (2003) distribution of a population across the five adopter categories (i.e., innovators, early adopters, early majority, late majority, and laggards) states that innovators represent only 2.5% of a particular population. In this research, even though 11% of participants perceived their *school* as being in the innovator category based on their PORGI (Hurt & Teigen, 1977) score, only 1.9% of *participants* (two individuals) were identified as innovators by their score on the Innovativeness Scale (Hurt, Joseph, & Cook, 1977). Thus, design-based researchers are not preparing their COTIs for wide scale adoption by teachers who are less innovative than their co-developers.

There is nothing inherently wrong with including innovator-teachers as co-developers on design-based research projects when the intent is to *develop* an innovation, and in DOI theory innovators are considered important to the *launch* of an innovation. However, DOI theory indicates innovators are not the most helpful to an innovation's *diffusion* because the venturesomeness of innovators reduces their credibility with other members of their peer network. Innovators simply adopt so many innovations so quickly their opinions about a particular innovation are discounted by their peers. Reliance on innovators who are inherently less effective communicators of the innovation means design-based researchers know less about how their COTIs will diffuse through the inter-personal communication channels that are at the core of Rogers' (2003) innovation-decision model depicted in Figure 1 in Chapter 1.

Third, Fishman et al. (2004) acknowledge design-based researchers employ an *emic*, or "insider" (p. 51), perspective, and this perspective is also intertwined with the non-diffusion of COTIs. Fishman et al. describe the contributions and limitations of the emic perspective as having “told us much about where to look for problems in the systemic uses of technology or reform more generally, but it has not provided guidance about how to *create* or *enable* change” (p. 51). Fishman et al. acknowledge that the emic perspective separates design-based researchers from other learning technology researchers who have an *etic*, or “outsider” (p. 51) perspective when they say, “The [etic] researchers or evaluators are almost never the same people who have worked to create the reform. By contrast, a feature of research on cognitively oriented technology innovations is that the researchers are usually developers of the innovation (ideally co-developers with the school participants)” (p. 51). Thus, Fishman et al. describe a feature of design-based research methodology key to the non-diffusion of COTIs. Design-based researchers are simply too close to the innovations they create and to the teachers who helped create them to effectively diffuse their creations.

In summary, three features of design-based research (i.e., highly supportive environments, reliance on teacher-innovators, and the emic perspective of design-based researchers) negatively impact the diffusion of COTIs in K-12 schools. Thus, the outcome of COTI development is often a small number of highly successful micro-adoptions of COTIs by their innovator-teacher co-developers and few successful macro-adoptions by school districts. When examined using DOI theory, this outcome is expected because design-based researchers are engaged in the development of innovations, not their diffusion. To expect design-based researchers to manage the diffusion of the COTIs they create is unrealistic. If Fishman et al.’s (2004) goal for COTIs to be widely adopted is to be realized, what is needed is a partnership between design-based researchers and diffusion-of-innovation researchers working in the learning technology field. Specifically, a partnership that employs DOI theory as embodied in the IAP is recommended. This discussion continues with a description of such a partnership and the benefits to design-based researchers, and hence K-12 schools.

The partnership between diffusion-of-innovation researchers and design-based researchers would begin as the development of the COTI is nearing completion and entering the field trial phase. Field trials of COTIs are currently part of the development process, but designed-based researchers conduct these in highly supportive environments and rely on competitive selection of teacher-participants (Peneul & Yarnall, 2005). A diffusion-of-innovation researcher could assist design-based researchers by co-operatively designing a second layer of field trial, similar to the one used in this study, including lower levels of support and non-competitive selection of teacher-participants. The second-level field trial could be preceded by a staff development experience akin to the workshop design used in this study. The purpose of these second layer field trial workshops is not to be the only occasion teachers in a population of interest learn to use a COTI, but rather an opportunity for COTI developers to learn about their COTI from teachers who did not participate in its development. Finally, the IAP methodology (i.e., point-of-adoption design, gathering quantitative and qualitative data from adopters and non-adopters) used in this study could be applied before and during the second-level field trial to provide design-based researchers with data they could use to revise their COTI for increased adoption in K-12 school districts.

This application of the IAP within a COTI-diffusion process would constitute a) a possible next step in the development of the IAP and b) a feedback mechanism for design-based researchers as they strive to increase COTI adoption rates. Benefits would be generated by providing design-based researchers with quantitative and qualitative data on perceptions of their COTI from large numbers of teachers in a short span of time. Using a protocol similar to the one displayed in Figure 7 in Chapter 3, a COTI could be presented to as many as 300 teachers over the span of two weeks (30 teachers per workshop, 1 workshop per workday). The analysis of the quantitative data from the surveys administered during the workshop, especially the IS (Hurt, Joseph, & Cook, 1977) and the PCIS (D.R. Compeau & Higgins, 1995), is envisioned as the core feedback design-based researchers would receive from the IAP. The analysis would provide adopter categorization and the perceptions of the COTI from “hundreds of teachers who do not share co-ownership of the design with the researchers and may lack specialized knowledge generated from the collaborative research process” (Fishman et al., 2004, p. 48). Results of the IS would allow researchers to determine the adopter category of individual teachers and identify teachers who are categorized as early adopters, the most desired adopter group because of their opinion leadership within their peer groups (Rogers, 2003). PCIS results would provide design-based researchers with direct feedback from teachers on each of the PCIs of the COTI. A logistic regression analysis of the PCIS results would indicate the role each PCI played in teachers’ micro-adoption decisions, thereby identifying those PCIs that are stronger indicators of the likelihood of adoption and providing design-based researchers with information they can use to adapt their COTI to increase its likelihood of adoption.

The qualitative data from an application of the IAP to a COTI diffusion would assist design-based researchers in two ways. First, follow-up interviews of workshop participants could provide detail on teachers’ perceptions of the COTI that may not have been captured by the PCIS. Thus, design-based researchers would have richer descriptions of teachers' decision making at the point of adoption. Second, during a second-layer field trial deep usage data could be collected and analyzed using the RAT taxonomy. Standardization on the RAT taxonomy (Hughes, 2000) would allow design-based researchers to leverage the non-linear nature of the RAT model to describe the effects COTIs have on teacher practice within a relatively short period time. This study demonstrated how the RAT taxonomy detects and describes changes in Richard and Julia's practice attributable to using RepliGo™ within the first week of the field trial.

Additionally, during a second-layer field trial the COTI could be diffused into a larger number of classrooms than occurred during the first layer of field trials. Increasing the number of classrooms using the COTI could serve as a test of its robustness and aid further diffusion by prompting design-based researchers to design support delivery models that do not rely so heavily on direct infusions of support from research staff.

To conclude this section, a partnership between design-based researchers and diffusion-of-innovation researchers could *potentially* increase macro-adoptions of COTIs by school districts. Potentially is the operative term because the sample size used in this study (i.e., an insufficient number of participants to investigate the full 15-factor IAP model) and the present early-stage development of the IAP preclude making a stronger claim. If such a partnership were to be pursued, design-based researchers would provide their emic perspective to the task of designing COTIs that meet the learning needs of students. Diffusion-of-innovation researchers would add their etic perspective to guide COTIs on a path towards widespread adoption. This would require effort on the part of both groups of researchers. Design-based researchers may have to grapple with revising their COTIs for macro-adoption while preserving the core principles that serve as the COTIs raison d'être. Diffusion-of-innovation researchers must expand the IAP methodology or develop new methodologies for gathering data on the large technology clusters that are COTIs as opposed to small innovations such as RepliGo™. However, if Fishman et al.'s (2004) ultimate goal that "the field will develop a body of examples of how cognitively oriented technology innovations come to be usable in a range of systemic contexts [i.e., schools and school districts]" (p. 55) is to be accomplished, then design-based researchers must be better informed about the impacts of their COTIs on teachers than they currently are. DOI theory and specifically the IAP methodology are a recommended starting point.

*Contributions to school leadership.* The adoption of systemic technology innovations by schools and school districts is not a simple process. Frank, Zhao, and Borman (2004) write that in schools "each actor has some autonomy to make his or her own decision partly in response to the ideas, information, and other social forces to which he or she is exposed" (p. 150). Thus, each time a school or school district adopts an innovation, the process "is not a simple matter of making a collective decision to adopt and then implement the innovation. Instead, the process is more one of *diffusion of innovation within the organization*" (p. 150, emphasis added). Schools or school districts make macro-adoption decisions when they decide to purchase or otherwise implement an innovation, then individual teachers use their autonomy to make their own micro-adoption decisions, and the success or failure of a district's macro-adoption hinges on the micro-adoption decisions of its teachers. The macro/micro-adoption dilemma in K-12 schools can be significant. The acquisition of a technology innovation along with costs for staff development and training represent a considerable expenditure for school districts that often occurs in a resource-constrained environment. Thus, there is a growing imperative for school leaders to *somehow* have their teachers use the technology innovations macro-adopted by the school or school district. One way school leaders are responding to this imperative is by mandating the use of technology innovations by teachers.

The macro-adoption of the Waterford™ Early Reading Program (Waterford™) by the Los Angeles Unified School District (LAUSD) (eSchool News, 2005a; Guerard, 2001; Helfand, 2005) illustrates the negative impact of mandating teachers' adoption of a technology innovation. In the case of LAUSD, the school district expended $44 million to macro-adopt computers and Waterford™ software, heralded by the district superintendent as "a major commitment to change" with high expectations for its success (Guerard, 2001). Two years after the macro-adoption the reading test scores of students in classrooms where Waterford™ had been installed were found to be lower than the scores of students where Waterford™ had not been installed. A subsequent evaluation determined that students were using Waterford™ 30-47% of the time recommended by its developer (Hansen, Llosa, & Slayton, 2004). In light of this finding the LAUSD "ordered schools to drop Waterford from daily language arts instruction and instead reserve it only for students who needed extra help" (Helfand, 2005). Thus, if Rogers' (2003) definition of adoption is used (i.e., "a decision to make full use of an innovation as the best course of action available"), Waterford™ was macro-adopted by the school district, but not micro-adopted by the primary grade teachers.

Mandated adoptions of technology innovations are increasing as schools and school districts consider ways to raise student achievement, especially in response to pressures from standardized testing and accountability measures. Some of these innovations are designed to be used by teachers exclusively (i.e., web-based grading systems, data warehouses), while others place the technology innovation into the hands of students (i.e., one-to-one computing, cognitively-oriented technology innovations, student responses systems). As evidenced by the statements of the LAUSD's superintendent upon the macro-adoption of Waterford™ (Guerard, 2001), school leaders have high expectations for these systems to improve student learning. Developers of technology innovations also have high expectations for the adoption of their creations (Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004; Lederman & Burnstein, 2006). Lederman and Burnstein (2006) propose student response systems (i.e., wireless handheld devices that students use to respond to multiple-choice questions during lectures) as a technology innovation that can satisfy, in part, the accountability requirements of the United States' No Child Left Behind Act of 2001. If a technology innovation is macro-adopted to meet federally-mandated accountability requirements, then its micro-adoption will most certainly be mandated.

Diffusion-of-innovation researchers (Brown, Massey, Montoya-Weiss, & Burkman, 2002; Ilie, 2005) are turning their attention toward mandated adoptions and how they may be different from voluntary adoptions. Brown, Massey, Montoya-Weiss, and Burkman (2002) define a *mandatory use environment* "as one in which users are required to use a specific technology or system in order to keep and perform their jobs" (p. 283). Brown et al. note the potential negative impacts of mandating the use of technology innovations: “While employees may use the technology, their job satisfaction, feelings toward their supervisors, and loyalty toward the organization can be severely and negatively affected.” (p. 283). In response to a need for definitions of use within mandatory use environments, Ilie (2005) developed the construct of usage she calls *shallow usage*. The term shallow usage was used earlier in this study to describe measures of use (i.e., frequency, duration) (Chin & Marcolin, 2001), but Ilie defines shallow usage as “minimal use of an IS [information system] as a response to coercive or mandated pressures from the part of management” (Ilie, 2005, p. 274). Thus, when school districts macro-adopt technology innovations and mandate their use, school leaders need a method to understand teachers’ attitudes toward the innovation in order to avoid the potential negative impacts described by Brown et al. and Ilie and the potential costs of a failed macro-adoption as experienced by LAUSD. Regardless of the kind of micro-adoption (i.e., mandatory or voluntary), school leaders also need indicators of teacher usage (i.e., shallow or deep) of micro-adopted innovations as a gauge of the effectiveness of their macro-adoptions.

Providing school leaders with a method to understand the indicators of teachers’ micro-adoption decision making prior to making a macro-adoption decision was one of the goals for this study. In the case of a technology innovation that will be macro-adopted with mandated teacher micro-adoption, the information provided by the IAP could be used by school leaders to inform their diffusion efforts and thereby avoid the pitfalls associated with mandated technology innovations indicated by Brown et al. (2002) and Ilie (2005). This section continues with an illustration of how the IAP methodology could be used by school leaders.

*Hypothetical example of the use of the IAP by school leaders.* The hypothetical example used in this illustration is the planned macro-adoption and mandated teacher micro-adoption of a student response system (SRS) throughout the core curriculum of Exulans High School (EHS). School leaders (i.e., the EHS principal and the district's technology coordinator) chose to macro-adopt an SRS in response to articles (Johnson & McLeod, 2004; Lederman & Burnstein, 2006) establishing SRS's usefulness for formative assessment. In its simplest form, an SRS consists of software loaded on a teacher's computer and small handheld devices similar to television remote controls distributed to students. Students push buttons on the handheld device to respond to multiple-choice questions presented by their teacher during a lesson, and the software rapidly tabulates and displays their responses on the teachers' computer. EHS school leaders want to know if they macro-adopt the SRS, will the teachers micro-adopt it, culminating in all 1,600 students in grades 9-12 at EHS using an SRS in all their core classes each day. For the sake of this illustration, it is assumed that all necessary resources are on hand to complete the macro-adoption.

EHS school leaders want to know (a) to what extent teachers will adopt the SRS in their classrooms when they are deployed, (b) what characteristics of the SRS should they emphasize when promoting the SRS, and (c) what characteristics of the SRS would inhibit teachers' use of the SRS. They implement an IAP protocol similar to the one displayed in Figure 7 in Chapter 3. A workshop is designed and teachers are selected to attend based on their adopter category as generated from their pre-existing IS data. Once the workshops are complete, data from the PCIS are aggregated, and means for each subscale (i.e., relative advantage, compatibility with current work practice, etc.) are calculated. Responses to a conditional adoption question are tabulated. Frequencies are reported for each of the PCIS subscales and for the responses to the conditional adoption question. Pre-existing IS results for each teacher are included with their responses to the PCIS and the conditional adoption question on individual reports that school leaders can examine. In this practical application of the IAP, it is assumed that the sample size is too small to sustain a statistical analysis, thereby only frequency distributions will be reported and interpretation will be assisted by use of appropriate charts and graphs.

The EHS school leaders use the results of their IAP to answer their questions. Their first question, “To what extent will teachers adopt the SRS?” is answered by examining the frequency of the conditional adoption question responses. School leaders pay special attention to the adopter category of each teacher to match it to his or her response to the conditional adoption question. For example, conditional adoption responses from teachers who are known laggards are examined to see if their underlying reluctance to adopt innovations holds true in the case of the SRS or if some other outcome is indicated. The second and third questions (i.e., what characteristics of the SRS should be emphasized when promoting the SRS, what characteristics of the SRS would inhibit teachers’ use of the SRS) are answered through an examination of the PCIS data. EHS school leaders can see from the bar graphs for each PCI measured by the PCIS which PCIs are more important to teachers and make plans to promote those aspects of the SRS.

For example, teachers found the SRS had high *communicability* and *measurability*. This means teachers agreed with the ideas that using an SRS was easy to talk about and the results of using an SRS were easy to describe. However, school leaders were surprised to see that one of the historically important PCIs, *compatibility with current work practice*, was rated very low by the majority of teachers. The school leaders treated this as a warning sign that teachers did not think it would be easy to integrate the SRS into their current practice. The EHS principal first checked this by talking with several teachers and, once this perception was confirmed, contacted the SRS provider to arrange for professional development targeted at this issue as part of the first wave rollout during the upcoming summer staff technology camps. The principal also told the SRS provider that if the problem with the system's compatibility was not addressed, it might impact the number of SRS handheld units EHS needed to purchase. The district's technology coordinator also arranged for additional time for EHS's technology integration specialist to prepare herself on this aspect of the SRS. Thus, this simple application of the quantitative portions of the IAP methodology provided the school leaders at Exulans High School with an opportunity to be proactive in addressing teachers' perceptions of an innovation and ground their expectations for the micro-adoption of the SRS by teachers in data provided by the teachers themselves.

In concluding this section, it is evident from the discussion that the value of this initial investigation of the IAP goes beyond the findings of particular factors that indicated participants' micro-adoption decisions of RepliGo™ and contributes significantly to both learning technology research and school leadership practice. The Innovation Adoption Profile (IAP) is a research protocol that, with additional trials and further refinement, could become useful to design-based learning technology researchers and school leaders as they work to either promote the diffusion of the innovations they have developed, select innovations for macro-adoption, and/or promote the diffusion of the innovations they have macro-adopted.

*Methodological Contributions to Diffusion of Innovations Research*

The second goal of this study was to respond to the call for reform in DOI research issued by Meyer (2004). This section discusses the methods used in this study as a response to Meyer's call.

This study employed a point-of-adoption design and deep usage measures of post-adoption outcomes to address the limitations of the dominant DOI research methodology. The dominant methodology relies on "quantitative data, concerning a single innovation, collected from adopters, at a single point in time, after a widespread diffusion had already taken place" (Meyer, 2004, p. 59). The use of a point-of-adoption design addressed Meyer's call by permitting data to be gathered during the critical early stages immediately before and immediately after teachers' micro-adoption decisions. This design alleviated the recall problem where "more information exists about what adopters think happened in the diffusion process than exists about what actually happened in the diffusion process" (p. 62) and addressed the pro-innovation bias problem by collecting data from both adopters and non-adopters.

The disregard for post-adoption outcomes was another problem in DOI research addressed by this study. Meyer (2004) noted that "a great deal, for example, is known about the extent of innovation adoption but much less is known about…the actual way in which the innovation is used" (p. 62). In this study the data needed to assess Richard and Julia's uses of RepliGo™ using the RAT taxonomy (Hughes, 2000) constituted deep usage data, or data that went beyond frequency and duration to measure usage "more tightly coupled to the actual act of technological use" (Chin & Marcolin, 2001, p. 10). This data were then re-analyzed using the PCI framework so as to complete the picture of the PCIs that indicated micro-adoption *and* deep usage.

This study confirmed the utility of the point-of-adoption design and the use of deep usage measures and also demonstrated that the PCIs can be used as an a priori coding scheme to analyze qualitative data. The Phase 1 and Phase 2 interviews were analyzed through an application of the PCIs, and Phase 1 adopters and non-adopters easily articulated the PCIs that informed their field trial participation decisions. During the four weeks that Richard and Julia participated in the Phase 2 interviews, they provided evidence of the PCIs that informed their usage. This usage of interview data is an extension of qualitative DOI research, building upon studies like Chiasson and Lovato's (2001) case study in two ways. First, data from twenty Phase 1 and two Phase 2 participants were analyzed as compared to a single individual in Chiasson and Lovato. Second, Chiasson and Lovato used an interview protocol that ensured they asked questions that explicated the PCIs (M.W. Chiasson, personal communication, February 23, 2006). The protocol in Phase 1 of this study asked a single open-ended question to elicit participants' reasons for their field trial participation choice. The advantage of the single-question protocol for this type of interview is participants were not prompted for the PCIs. Rather, the PCIs emerged from the reasons participants gave for their choice to accept or decline the invitation to participate in the field trial of RepliGo™ . As explained in the Results section, the Phase 2 interviews were conducted with the RAT taxonomy (Hughes, 2000) in mind. Only after the RAT analysis was complete were the interviews re-coded with the PCIs. Thus the PCIs still were evident even when the interview protocols were not designed to explicitly elicit them.

*Limitations of the Study*

This study acknowledges limitations that narrow the generalizability of the results. This section describes three general limitations that affected sample size and quality of the data and concludes with a discussion of limitations specific to DOI research.

*Limitations pertaining to sample size and data quality.* The Phase 1 sample was smaller than could sustain the logistic regression analysis of the 15-factor IAP model. The small sample was due in part to the loss of data caused by the unanticipated technical complications, but also to differences between the district administration's preferences for delivering staff development experiences and the preferences of teachers participating in those experiences. When approached to approve this study, district-level officials recommended that workshops occur in late April and early May so teachers could participate in a field trial of RepliGo™ during the last four weeks of the school year. They also recommended the workshops be conducted in the district's centralized service center and e-mail be used to advertise the workshop. It was later discovered that the late-April-early-May timeframe was what teachers called their "final five" (i.e., the last five weeks of the school year), and very few of them were interested in staff development during this time. Teachers also informed the researcher that traveling to the district's central service center was inconvenient, and they preferred to receive their staff development in their buildings. Finally, teachers said they did not find the district's email announcements of staff development opportunities particularly attention-getting, and they preferred to attend opportunities announced at their building-level staff meetings. With this knowledge and the assistance of the district's assistant superintendent, the researcher met with the building principal of Madison High School, arranged to include the August workshops in a scheduled staff development day and appeared at a faculty meeting to announce the workshop and answer questions from teachers. By comparison to the April-May workshops, the August workshops were well attended. Researchers working with teachers may be well-advised to attempt to inquire of their target audiences (i.e., teachers in this case) how best to arrange contact rather than relying on others (e.g., the district) for managing the logistics that are such a crucial part of performing research.

A second limitation most likely affected the sample size for Phase 2 of the study when teachers were invited to use RepliGo™ in their classrooms. This study attempted to replicate, to the greatest extent possible, all the elements involved in introducing a technology innovation to teachers. However, unlike real-world innovation adoptions, the support available to teachers adopting RepliGo™ was minimal due to resource constraints. No additional training was provided, and technical support consisted only of a webpage that included links to how-to guides and screen captures of the RepliGo™ interface. In addition, no technical support for downloading or installing RepliGo™ on student laptops was available. Teachers were informed of the level of support for their implementation after making their micro-adoption decision (i.e., to participate or not participate in the field trial). While it was unlikely that the level of technical support played a role in their micro-adoption decisions, teachers did consider this when following through on their choice to participate in Phase 2 of the data collection. It is anticipated that a school district implementing a technology innovation would provide greater levels of technical support to users of the innovation than was provided to the participants in this study.

A third limitation in this study is one common in educational research: All data used in this study were provided by the participants. While Phase 1 survey data was triangulated by the follow-up interview data, this was only from one-third of the participants. Phase 2 interviews with Richard and Julia were not triangulated with use of in-class observations. Unlike Hughes' (2000) study where she initially developed the RAT taxonomy; this study did not use classroom observations to verify what Richard and Julia said during their telephone interviews.

*Limitations specific to DOI research.* The majority of participants in this study were all teachers in laptop schools. At the time of this writing, laptop schools are at the leading edge of technology implementation, and the participants' school district has received numerous awards for their innovative approaches to the uses of educational technology and the innovativeness of their programs in general. The PORGI (Hurt & Teigen, 1977) results indicated that participants were aware of the district's innovativeness, and the IS (Hurt, Joseph, & Cook, 1977) results indicated they were individually more innovative as a whole than what was theoretically expected. Thus, as stated earlier, while innovativeness was not an indicator of this sample's micro-adoption decisions regarding RepliGo™, this may be true only for this population of highly innovative teachers in what appears to be an extraordinarily innovative school district. Thereby, the innovativeness construct is retained in the revised IAP model, but not as a direct indicator of teachers' micro-adoption, but rather as a way to gather context for the results of the PCIS (D. R. Compeau & Meister, 2003). Retention of the innovativeness constructs in the IAP is deemed valuable because knowing the level of innovativeness of teachers who are providing their perceptions of an innovation may be useful as a way to triangulate those perceptions.

Another limitation that impacts the IAP model's effectiveness in indicating teachers' micro-adoption decisions is the lack of a measure of participants' prior experience with using technology. Without a measure of prior experience, it is unknown if participants' prior experiences factored into their micro-adoption decisions. While prior experience with technology was not part of the IAP model used in this study, a plan to gather pre-existing data on prior experience with technology was included in the initial design. This plan was stymied by technical complications at the state agency responsible for storing the data and participating teachers' ability to access such data. To reduce the need to collect pre-existing data and allow the IAP to be used in contexts that do not routinely collect prior experience data, future revisions of the IAP will include measures of teachers' prior experience with technology. However, care must be taken to avoid making the IAP surveys so long they are burdensome to participants.

There is an implicit limitation operating in the choice of the school district for this study. In addition to the impacts of innovativeness mentioned earlier, the ubiquity of laptop computing in the district significantly reduced the size of the innovation examined in this study. When one innovation adoption (i.e., RepliGo™ in this study) is dependent on another (i.e., the laptops required so that each student had unfettered access to their reading material in RepliGo™) and both are introduced simultaneously, the PCIs of the two innovations can become intertwined and difficult to distinguish. Rogers (2003) calls this the *technology cluster* problem and says, "The problem is how to determine where one innovation stops and another begins" (p. 14). Because this district already had diffused laptops, this meant RepliGo™ was not clustered with other innovations, and the technology cluster problem was reduced. Monitoring for the presence of technology clusters is important to consider when performing DOI research (Rogers, 2003). For example, when the innovation is a computer, it is possible that there are really multiple innovations being diffused at the same time: A new way of communicating via e-mail, a new way of gathering information through the Internet and weblogs, a new way of working in each content area using specific tools, etc. All of these innovations are clustered with the computer. Thus, it is important to consider the technology cluster problem when performing DOI research, especially when complex technology innovations are the focus of interest or when an innovation relies on other innovations in order to be diffused.

Finally, while this study did respond to Meyer's (2004) call for reform in diffusion of innovations research, it did not address each part of that call. This initial investigation of the IAP only examined a single innovation, RepliGo™, being diffused through a single population, the 60 participants who were included in the logistic regression. Further, the follow-up interviews were conducted only with a convenience sample; a more robust design would have included resources to interview all participants. Thus, the full appraisal of the IAP as a method to inform school leaders of the indicators of teachers' micro-adoption decisions must wait for replication of the study with other innovations and populations.

*Future Directions*

As stated earlier, this initial investigation of the IAP was conducted under conditions that did not fully mirror a real technology innovation adoption. In essence, while participants' micro-adoption decisions were authentic inside the paradigm of a research study, there was no district-supported macro-adoption for this application of the IAP to inform. Thereby, the next step in the investigation and refinement of the IAP should be to fully embed the IAP into the context of a real macro/micro-adoption of a technology innovation in schools. School districts could use the IAP in situations where a technology innovation was under consideration for macro-adoption or in situations where a macro-adoption has already occurred and micro-adoption has not yet begun. Dissemination of the revised IAP as a self-contained protocol could foster this form of replication.

*Conclusion*

In this discussion, the methodological contributions of the study as a response to calls for reform in diffusion of innovation research were illustrated and digital annotation was established as an innovation worthy of expanded attention from reading comprehension researchers. In the field of learning technology, the IAP was constituted as a methodological approach worthy of future exploration in partnerships with design-based researchers and school leaders as they address the persistent macro/micro-adoption dilemma.