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An Examination of the Characteristics Impacting Collaborative Tool Efficacy: The Uncanny Valley of Collaborative Tools

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Abstract

As collaboration among teams that are distributed in time and space is becoming increasingly important, there is a need to understand the efficacy of tools available to support that collaboration. This study employs a combination of the Technology Acceptance Model (TAM) and the Task-Technology Fit (TTF) model to compare four different technologies used to support the task of collaboratively creating and editing a report. The characteristics of the four technologies operationalize different collaborative processes and quality of the editor enabling the examination of how well each addresses previously identified challenges to electronic collaboration. The study compared the use of MS Word combined with emailing the document among collaborators, Twiki, Google Docs, and Office Live by university students to collaboratively write a research paper. The study measured Task-Technology Fit, Perceived Ease of Use, and Perceived Usefulness of the technologies. The findings suggest that certain technological factors associated with the collaborative tool can impact effective use of the tool. A powerful interface with which the user has some experience is necessary, and support for distributed collaboration can be the distinguishing factor in making a tool an effective collaborative writing and editing technology. Our study suggests that Word/email and Google Docs outperform Twiki and Office Live due to tool experience and superior Task-Technology Fit that may be due to the sophistication of the writing and editing tool, support for collaboration, and the clarity of the collaboration process.

We speculate that the surprisingly poor showing for Office Live is due to mixing a familiar editing interface with a collaborative model that is different from students' mental model of collaboration, leading to a phenomenon similar to the 'Uncanny Valley,' which is the experience of many people when interacting with humanoid robots and animations that have very good, but not perfect, realism.

Keywords: Collaboration, Collaborative writing, E-Collaboration, Wiki, Word processing, Google Docs, Office Live, Task-technology Fit, Technology Acceptance Model

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Introduction

In general, organizations that are more collaborative perform better (Frost & Sullivan, 2006). To this end, organizations are relying increasingly on virtual teams to perform a range of activities (Hertel, Geister, & Konradt, 2005). Because members of virtual teams do not necessarily work in close proximity, finding ways to support collaboration effectively among members raises new challenges. Although a variety of factors affect collaboration, including organizational culture and de-centralized structure, technology is the primary tool in supporting collaboration in virtual teams. In recent years, several technologies have been developed to support e-collaboration, including wikis and online office suites, like Google Docs and Zoho. Even the venerable off-line giant, Microsoft, has made moves to support online collaboration through its Office Live and subsequent Office 365 offerings. However, the efficacy of these technologies in supporting virtual teams has not been adequately studied.

Collaborative work is also pertinent to the educational field. Many college courses involve group work where teams of students are asked to create a report as the final result of a collaborative effort. Creating such a shared document often causes students great trouble in coordinating the effort when using traditional tools. Educators were early adopters of wiki technology as a way to increase student engagement and collaboration within the classroom (Parker & Chao, 2007) and have continued with other Web 2.0 collaborative tools (Brodahl, Hadjerrouit, & Kristian, 2011). Educational uses of wikis included creating a shared annotated bibliography of class readings; developing shared lecture notes; publishing syllabi, assignments, and handouts; and having students collaborate on shared documents such as research papers, reports, study guides, and article critiques (Chu, 2008; Hazari, North, & Moreland, 2008; Watson, Boudreau, York, Greiner, & Wynn, 2008). Again, the efficacy of the tool use in education has not been systematically evaluated.

In a previous study, we examined how Twiki compared with a combination of Microsoft Word and email when used to complete a collaborative task in a virtual team (Dishaw, Eierman, Iversen, & Philip, 2011). The results from having 552 undergraduate students complete a project in groups of three, showed that:

1. There was no difference between the groups using Word and the groups using Twiki regarding the perceived effort required to collaborate on the project.
2. Students using Word and email perceived the Task-Technology Fit to be better than students using Twiki.
3. Word and email was perceived to be more useful than Twiki in completing the project.
4. Word and email was rated easier to use than Twiki.

The first three of these results were somewhat surprising as the Twiki tool was designed explicitly to support collaborative work. However, the last finding, that Word and email was easier to use, was not surprising, as the Twiki tool had a relatively simple editing interface, typical of web editors of the time. Overall, our conclusion was that "there currently is no advantage for students in using wiki technology in a collaborative writing assignment." (Dishaw et al., 2011) However, this conclusion, although interesting, does not sufficiently answer why these results were observed.

In this paper, we expand on the previous study by including two additional technologies: Google Docs and Office Live. Both these technologies operationalize the collaborative writing and editing in a manner that should help explain why the previous results were observed. With a wiki there isn't a notion of a traditional document – instead, the users build a website consisting of multiple inter-linked pages. The addition of Google Docs enables comparison with a technology that has the same central collaboration model as a wiki, but instead of web pages, it employs a document-based model similar to MS Word. Including Office Live, which uses MS Word as the editor, but a central document repository in the cloud, enables a comparison with a rich editor like MS Word but with a different collaboration model.

In this paper, we explore these issues deeper and determine if other technologies may be more suited than wikis to challenge the combination of Word and email in collaboratively writing a paper and to understand why the efficacy of the tools may differ.

Theoretical Background

The idea that information technology could support communication and collaboration has been around for a number of years (Markus, 1994; Orlikowski, 1993). The primary goal of this support is connecting individuals across time and space to support the completion of some task. Electronic collaboration (e-collaboration) has been broadly defined as using electronic technologies by the members of a team to accomplish some task (Kock, 2005). E-collaboration has been studied in a variety of areas such as project management (Leuthold, Huber, & Plüss, 2012; Sonnenwald, 2010), interorganizational learning (Choi & Ko, 2012), supply chain (Chong, Ooi, & Sohal, 2009; Saosaovaphak, Shee, & Sadler, 2009), manufacturing (Rosenzweig, 2009), and systems analysis (Bragge & Merisalo-Rantanen, 2009). Although these studies cover a diverse set of subject areas and use a diverse set of e-collaboration technologies, there are relatively few studies of e-collaboration in support of collaborative document creation.

Hazari et al. (2008) found that wikis can promote collaboration in group assignments. Further, a case study by Chu (2008), where students worked in groups to develop a chapter for a wikibook (an online book created with wiki technology), found that the students thought that the use of a wiki improved both their collaboration and the quality of their work. However, Dishaw et al. (2011) found that students perceived that exchanging MS Word documents via email to be a better fit for the collaborative writing task than using a wiki. Blau and Caspi (2009) found that the perceived quality of the resulting document was increased when drafts were shared with others for suggestions or editing via Google Docs. However, they found that students felt that others reduced the quality of the document if the collaborator actually edited the individual's own text rather than just reading the document or suggesting changes. Rienzo and Han (2009) found that students have a preference for Google Docs' real-time editing capabilities and the familiarity and robustness of Office Live. However, they do not evaluate the impact of these tools during execution of an actual task.

An assessment of collaborative technologies by Nosek and McManus (2008) suggests that they are not as effective as they might be. They suggest that challenges facing effective e-collaboration include 1) group process challenges, 2) theoretical challenges that limit the scope of work and new conceptualizations, 3) conceptual challenges that affect what individuals conceive of doing with the technology, 4) technical challenges that limit what the technology can do, and 5) use challenges that suggest usefulness is the only predictor for continued acceptance and use of a technology (Kock & Nosek, 2005; Nosek & McManus, 2008). Kock (2008) suggests that the basis for this lack of effectiveness may be rooted in the lack of media richness and media naturalness in e-collaboration technologies. When media lack richness and naturalness, they are thought to pose obstacles to communication because they do not have key characteristics present in face-to-face communication. Our previous study (Dishaw et al., 2011) identified three of the above five challenges to effective e-collaboration as possible explanations for the finding that Twiki was not perceived to support the task as well as MS Word/email.

First, students are likely to have a cognitive model of how group processes are traditionally carried out, which involves using word processing to write and edit a paper and email to share. The students work on group projects in most of their courses at the university, but they are neither required to use a specific tool to support their work, nor provided with alternatives. Hence, they use MS Word and email, which are available and familiar. Because using a wiki requires a change in process, the adaptation may cause challenges that are reflected in their perceptions of the usefulness and ease of use of the new tool.

Second, conceptual challenges for individuals could be important. Students have a lot of experience using word processing software and likely have a very strong mental model of how to use this tool in editing a document. In contrast, although Twiki has some features similar to word processing software, its editing interface is different and its capabilities are much less sophisticated. This difference, even though students received instruction on Twiki, may have led to the perceptions of lower usefulness and ease of use because it did not fit their mental model of the task.

Finally, technical challenges are likely related to the conceptual challenge previously discussed. Twiki does not have a sophisticated interface with the same power as the word processing software. The quality of the interface has been suggested as potentially playing a key role in the success of collaboration technologies (Garza & Kock, 2007). Additionally, tracking changes in a Twiki document requires reviewing its history of different versions in different windows, which can be more confusing than tracking changes in MS Word. On the other hand, the history function of Twiki is far more robust than in Word, as it reliably keeps every version of the document, and students reported anecdotally that they found it very useful to be able to see who had made recent changes to the document. Also, if a group wanted to prevent others from seeing their work, the Twiki procedure for doing this is both difficult and unreliable. All these issues may contribute to the lower usefulness and ease of use perceptions of the Twiki collaboration technology.

In an effort to understand the factors that may be contributing to the perception that exchanging Word documents via email is "better" than using Twiki for collaborative document creation, we include Google Docs and Office Live in this study to include tools with functionality that differ along several dimensions. We assess the technology's impact using Task-Technology Fit theory.

Information systems research has used different approaches to assess the impact of a technology on the performance of a task and the utilization of the technology to perform the task. One widely accepted and used approach is the Technology Acceptance Model (TAM), which is used to determine the acceptance and eventual use of a technology based on the potential user's attitude toward using the technology (Davis, 1985).

The TAM suggests that the user's perception of the technology's ease of use impacts his/her attitude toward use of the technology and his/her perception of its usefulness. Perceived usefulness, in turn, impacts the attitude toward use. Both perceived usefulness and attitude toward use impact the intention to use the tool, which in turn, impacts actual use. Numerous studies have replicated Davis's (1985) study providing significant empirical evidence for the model (Adams, Nelson, & Todd, 1992; Davis, 1989; Grover & Sengars, 1993; Massey, Cronan, & Hendrickson, 1993; Subramanian, 1994; Szajna, 1994). The model has been used in more than 100 studies to examine technology acceptance in a variety of settings (Chuttur, 2009). However, Chuttur (2009) has criticized the model as having limited explanatory and predictive power as well as a lack of practical value.

The TAM also has seen significant use to examine students' use/acceptance of information technology in education (Padilla-Meléndez, Garrido-Moreno, & Del Aguila-Obra, 2008). Dasgupta, Granger, and McGarry (2002) studied electronic collaboration technology specifically and found that TAM works well in understanding its acceptance and that perceived usefulness had a significant impact on actual use of the system. Other studies also confirm the efficacy of TAM in education. For example, Selim (2003) analyzed perceived usefulness and ease of use as predictors of the acceptance of web-based courses. Martins and Kellermanns (2004) also used TAM to determine that these two constructs impact the acceptance of web-based courses. Finally, Lee, Cheung, and Chen (2005) and Gong, Xu, and Yu (2004) suggest that an enhanced TAM can improve understanding of information technology acceptance in education. One such extension is Task-Technology Fit (TTF).

Task-Technology Fit (TTF) assesses the perceived fit between a user's task needs and the functionality provided by the technology (Goodhue, 1995; Goodhue & Thompson, 1995). Dishaw and Strong (1999) combined TAM with TTF to introduce the TAM/TTF model (**Figure 1**). The TAM/TTF model is a well-established extension to TAM that has more explanatory power than either model alone (Dishaw & Strong, 1999). The TAM/TTF model also has been used in over 100 studies to examine technology acceptance in a variety of settings. The TTF extension to TAM suggests not only that ease of use and usefulness indirectly impact acceptance of a tool, but also that ease of use and usefulness are impacted by the fit between the technology and the task, and that this fit also directly impacts acceptance (actual tool use in the model). This model also considers the effect of the user's experience with the tool on perceived ease of use and usefulness.

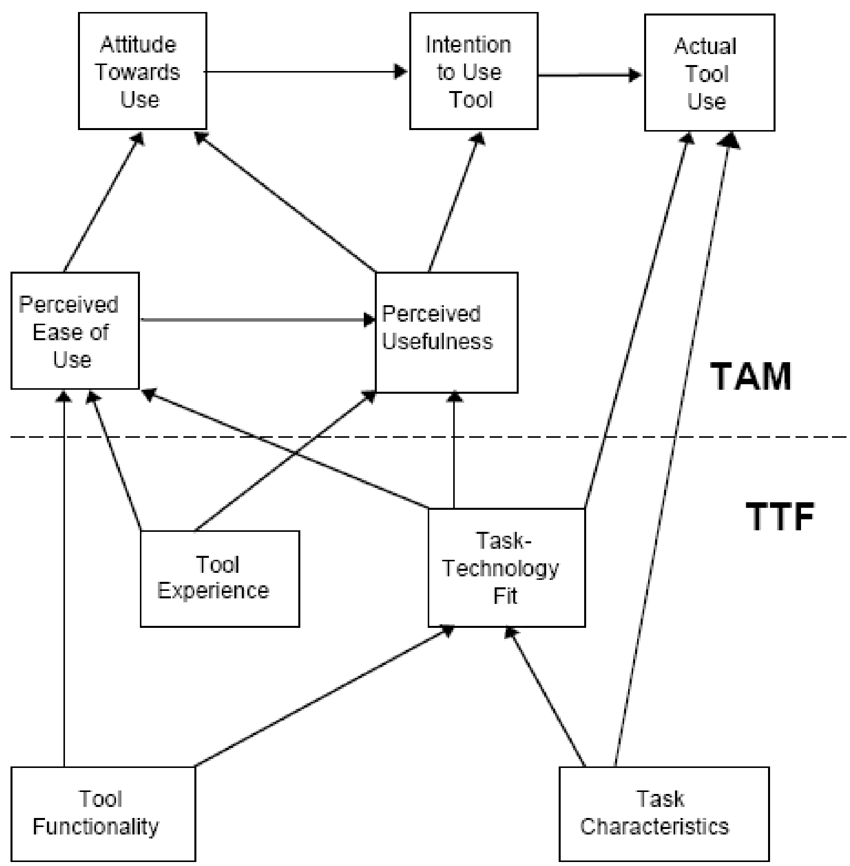

Figure 1. Combined TAM/TTF model

The increased emphasis on collaboration in both the workplace and education and the recent focus on web-based technologies to support this collaboration suggest that understanding the efficacy and acceptance of these technologies is important to future decisions concerning deployment of this technology. Past research in information systems has relied upon the concepts of acceptance and fit to explore these questions. This study uses the TAM/TTF model to begin exploring these questions.

Research Model

This study uses an adaptation of the combined TAM/TTF model (**Figure 2**) developed by the authors (Dishaw et al., 2011) to examine the research question:

> *What technological factors impact user perceptions of the usefulness and ease of use of collaborative tools?*

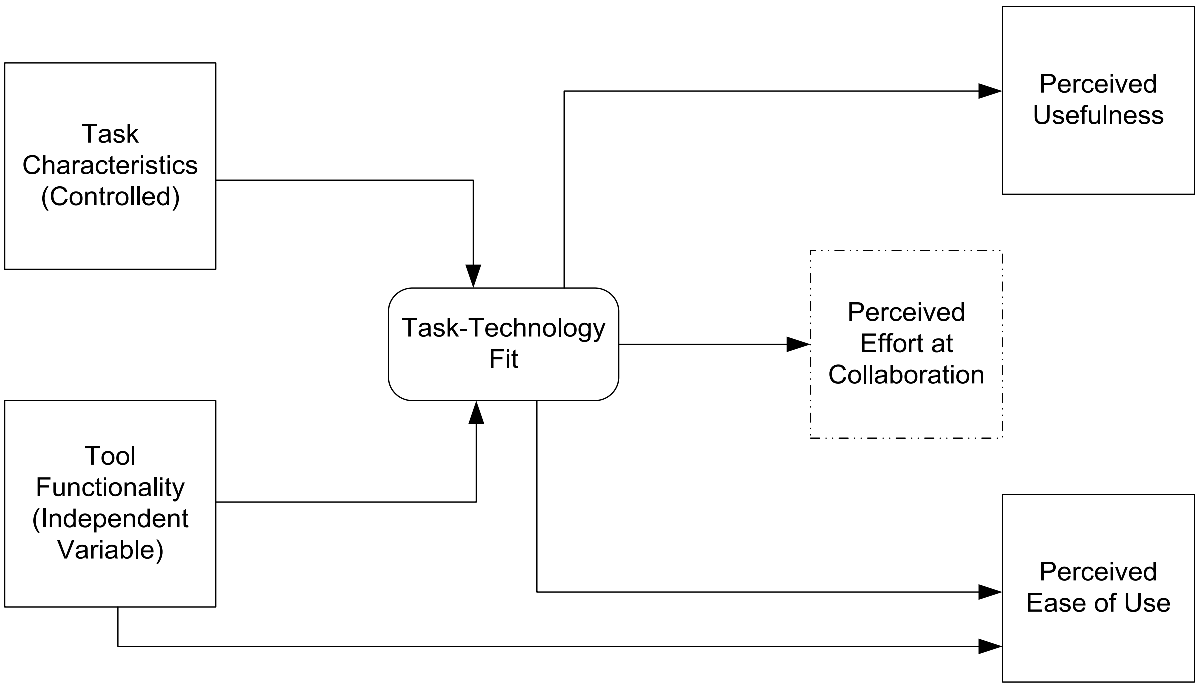

Figure 2. Research model

The dependent variables measured are the TAM variables Perceived Ease of Use and Perceived Usefulness and a variable developed for the previous study: Perceived Effort of Collaboration. The Perceived Effort of Collaboration construct was added to specifically address the study's focus on collaborative writing and editing. In the previous study (Dishaw et al., 2011) we speculated that the differences in the collaborative process enabled by each tool may help explain why one tool was perceived to be "better" than the other. That study found that subjects did perceive a difference in the effort of collaboration, justifying its continued use in the current study. Ease of Use and Usefulness are used instead of the TAM variables Attitudes Toward Use, Intention to Use, and Actual Tool Use because the users were required to use a particular technology. Because they did not have a choice, these variables became irrelevant. Additionally, research by Davis (1985) and Dishaw and Strong (1999) established that Ease of Use and Usefulness have significant impact on Attitudes toward Use and Intention to Use.

The independent variables measured are the TTF variables Task Characteristics and Tool Functionality. The task characteristics variable is held constant across treatments by assigning all subjects the same task (to write a group paper). Tool Functionality is varied between subjects. There are four treatment groups based on the tool used: Twiki, MS Word Documents exchanged via email, Office Live, and Google Docs.

In the original study (Dishaw et al., 2011), we examined Word compared to Twiki. As **Figure 3** shows, there are significant differences between these technologies regarding three important characteristics. First, Twiki has a central document location, whereas Word documents are stored locally on each collaborator's machine. Second, Twiki doesn't use a traditional notion of a document, but instead uses web pages. Third, Twiki has a simple and crude editor compared to a very powerful editor in Word.

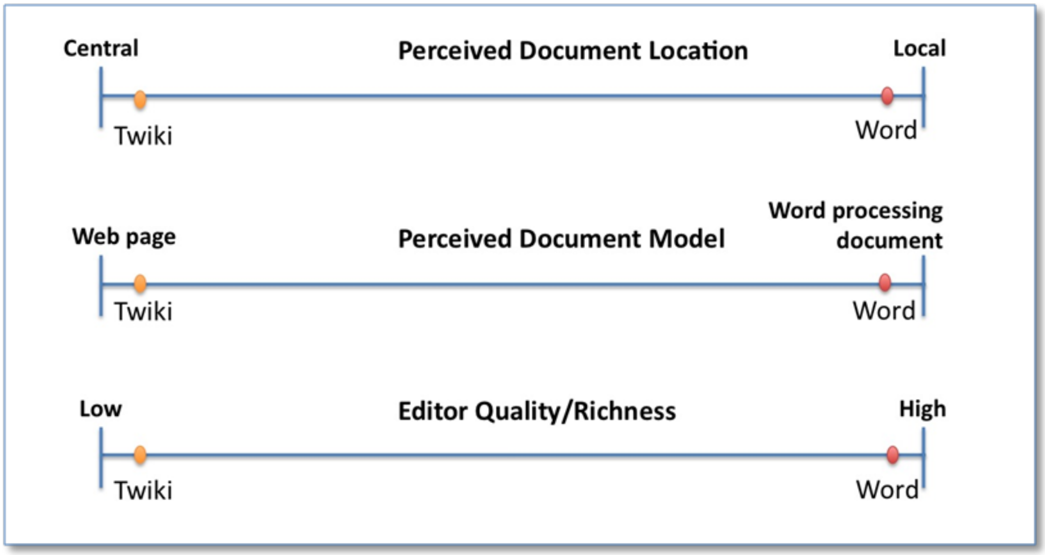

Figure 3. Technologies in original study arranged along three dimensions

The original study showed a significant difference between the Task-Technology Fit of the two technologies. To help examine this difference in terms of the role played by the tool characteristics, we introduced two new technologies, Google Docs and Office Live, which are similar to Word /Wiki in certain characteristics, but different in others. As seen in **Figure 4**, Google Docs has the same central document location as Twiki, but the document model and the quality of the editor is closer to that of Word, and significantly different from Twiki. Office Live also has a traditional Word-like document model and editor, and physically, the Office Live document is located centrally like Twiki. However, it may not appear to be quite central because there is no real time update of documents during concurrent editing and because of its resemblance to the familiar Word. Because Office Live combines the strong editing experience of Word with built-in support for collaboration, it seems to have the best of both worlds.

The introduction of the new technologies led us to speculate that how closely the technology's editor matched the notion of a traditional word processing document would be important to some students. Several elements make up our notion of a word processing document, such as a representation of pages and margins. Closely related to the notion of a document is also the concept of a file and how documents are opened. The differences between the technologies with regard to these concepts are represented on the Perceived Document Model scale in Figure 4. The further a technology is placed to the right, the more elements of a traditional word processing document are manifest in that technology. This study does not attempt to determine the exact role of each of the characteristics in determining Task-Technology Fit.

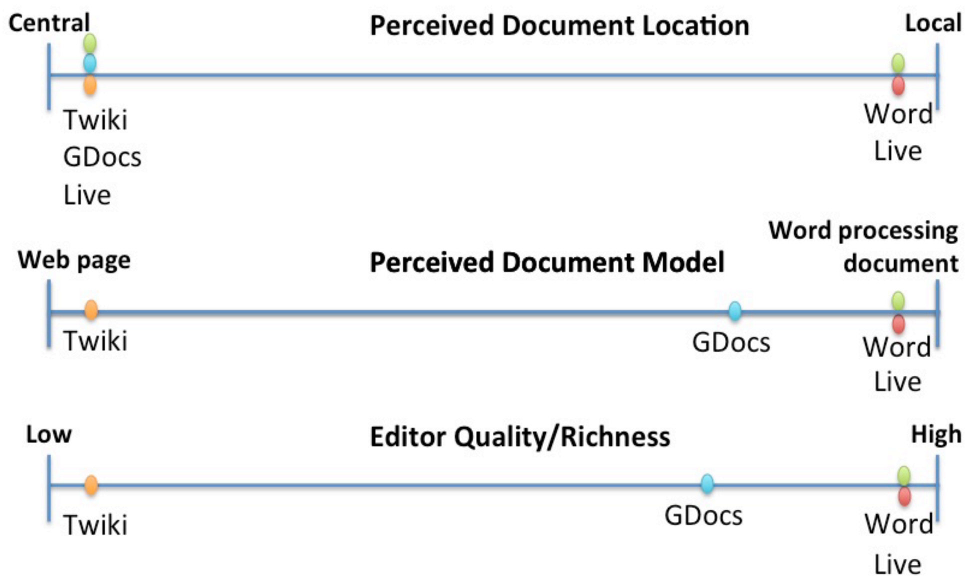

Figure 4. Technologies in current study arranged along three dimensions.

The perception of where the document is stored could also influence students' use of the collaborative technology. For Twiki and Google Docs, it is clear that the document exists only in a central location, since a web browser is required to access the document. While it is possible to save local copies of the document, this is not an obvious and logical way to work with these tools. When using Word, it is also clear that the document is stored as a local file and that a file must be exchanged in order for collaboration to take place. However, with Office Live, it is much less clear how students perceive the document location. While the document is technically stored centrally, the use of the familiar Word interface and the way concurrent edits are handled may confuse the location of the document, so it is placed at both the Central and Local ends of the Perceived Document Location scale.

With regard to the Editor Quality/Richness characteristic, we placed the four technologies based on our experience with the tools. Word and Office Live use the same editor, and while it may be complex for some users, it is undeniably the richest and most powerful editor included here. Twiki is also clearly much less powerful and difficult to use. Google Docs is placed in between as it is much better than Twiki, but is missing many features that Word offers.

Table 1 shows the differences among the four technologies along several characteristics. These characteristics include the three previously discussed and three additional characteristics that are relevant in comparing the four tools. These characteristics are grouped into two dimensions: 1) the quality and richness of the editor, and 2) collaboration support that represents the integration of the editing and collaboration tools, the document model and location, the collaborative process and the ability to track changes. The table also includes some of the potential collaboration problems that might be present in each technology

Table 1. Overview of the technologies

Technology	Editor Quality/Richness	Collaboration Support: Integration between editing and collaboration tools	Collaboration Support: Document Model & Location	Collaboration Support: Collaborative Process	Collaboration Support: Track Changes	Potential Collaboration Problems
Wiki	Simplistic with limited tools	Fully integrated: Collaboration built into the tool architecture	Web pages in a central location	Latest document always available online	Built into every page. Must go to separate page to view. Can be difficult to interpret.	No notification mechanism. Must use email to keep collaborators updated.
Word/email	A large number of formatting tools accessible in many ways, including grammar and spelling support	No integration: Must exit the editing tool (Word) to use the collaboration tool (email)	Documents stored locally	Email document between participants; Can write/edit parts independently then combine into single document	Changes visible on every page. Can be difficult to track history. Editing can remove change information. Computer may not be configured properly with user name (especially in labs).	Potential serialization. Difficult to keep track of current version.
Google Docs	Many tools for formatting	Collaboration is integrated into the editor as well as the document manager interface	Documents stored centrally	Concurrent editing with real-time update. Email, real-time chat and threaded comments available within the tool	Automatically available (built-in). Must go to separate page to view. Cannot be deleted.	Frequent changes to the tool make learning difficult.
Office Live	Very similar to MS Word	Some integration: Collaboration only available in web interface, where commenting is only available in Reading Mode, not Editing Mode	Documents stored centrally, with option for local editing in Word or central editing using web	Concurrent editing, but updates visible only after saving by both	Same as Word/email when using Word to edit, but track changes not available in web interface	Using familiar tools with little change in the UI but significant change in mental model of collaboration. Save button reconfigured to save and upload changes for others to view, and to view the latest changes.

There are interesting differences among the four tools in the integration between the editing and collaboration interface, the collaborative process and tracking features. With Twiki, there is only one tool, the web page where editing takes place, with no explicit tool support for collaboration Thus, there is no distinction between the editing and collaboration interface. In Google Docs, the collaboration tools, such as controlling sharing and real-time chat, as well as viewing the history of changes, are integrated into the editing interface. At the other end of the spectrum, the Word/email combination has several tools involved, but each has its own distinct responsibility. Word is used for editing, the operating system for managing the files, and the email for the collaboration.

In the middle is Office Live, where there are two options for editing: 1) Word, or 2) the web-based editor that has a Word-like interface with certain features like tracking not available. There are no collaboration features in the editing interface other than commenting in “Reading Mode.” The collaboration (e.g., share, chat, and email) is done primarily on the documents management page. The option to save a document is replaced with a “Refresh” feature that uploads local changes and downloads changes from other users.

The TAM/TTF model suggests that Tool Experience impacts Perceived Ease of Use and Perceived Usefulness. Tool Experience was not measured in the original study because it was assumed that subjects would have significantly more experience with the MS Word/email model of collaboration than Twiki, and therefore tool functionality and tool experience would be significantly correlated. Although this assumption was no longer valid with the addition of Google Docs and Office Live, the study was not altered so that other confounding factors would not be introduced. However, tool experience was collected independently from a subset of the subjects to help explain the results.

The Task-Technology Fit variable is included in the research as an interaction term of the two independent variables. Differences found in the constructs that make up this variable indicate that there is a difference in the fit of the tools to the collaborative writing and editing task.

Hypotheses

Our earlier research (Dishaw et al., 2011) determined that there was a difference in Task-Technology Fit, perceived ease of use, perceived usefulness, and perceived effort of collaboration between Twiki and MS Word/email. The MS Word/email tool was found to be a better fit and had better perceptions of ease of use, usefulness, and effort of collaboration. This research seeks to explain this finding by including tools with different functional characteristics to examine which characteristics lead to a better fit with the task. The first hypothesis tests whether or not there is a different Task-Technology Fit between tools.

Hypothesis 1: There is no difference in Task-Technology Fit between the four tools.

If this hypothesis is rejected, it will suggest that one or more of the technologies is a better fit with the collaborative writing task than the others. A difference in fit by itself does not imply a “better fit.” To examine the question of better fit, differences in the dependent variables Perceived Ease of Use and Perceived Usefulness need to be tested. If established that there is a difference in these variables, a higher value will be interpreted to mean a “better fit.” The second hypothesis tests whether there is a difference in ease of use between tools.

Hypothesis 2: There is no difference in Perceived Ease of Use between the four tools.

The third hypothesis tests for differences in usefulness between tools.

Hypothesis 3: There is no difference in Perceived Usefulness between the four tools.

The fourth hypothesis tests for differences in Effort of Collaboration. If there is a significant difference, a higher value will be interpreted to mean that more effort was perceived to be required. A difference in the effort of collaboration may be an explanation for differences in Task-Technology Fit and the other outcome variables.

Hypothesis 4: There is no difference in Perceived Effort of Collaboration between the four tools.

Research Design and Methodology

This study uses a field experiment to test the hypotheses. The study keeps the task constant and varies the technology by assigning a tool to each group. The subjects are students in different sections of the same course. All sections used the same task and all subjects in a single section used the same tool. The tool was varied by section. Tools used were Twiki, MS Word/email, Google Docs, and Office Live. The unit of analysis is the individual subject participating in the task. Data is collected via survey at the end of the course.

This research project is based on teaching the course "Essentials of IS," which is required for all business majors in the College of Business where the study took place. Data was collected in the Fall 2007, Fall 2008, Spring 2009, Fall 2009, Spring 2010, Fall 2010, Spring 2011, Fall 2011, and Spring 2012 semesters, with a total of 1002 students participating in the study. All sections were taught face-to-face to a mostly traditional undergraduate college population (18-22 year olds) of full-time students originating from the local area (very few international students). The population is roughly equal in terms of gender. Most students take the course as sophomores and juniors. The course was taught in multiple sections by three faculty members. Instructors who taught multiple sections in a semester used the same technology in all sections. Table 2 shows how many students used each technology and the response rate for the survey.

Students in sections assigned to use word processing and email were shown how to use the Track Changes feature of MS Word to help identify changes made by different group members. They were not given specific instructions on how to collaborate; however, they were asked to use email for communication and exchange of documents.

Table 2. Details of study

Technology	Enrolled	Responses	Response Rate
Twiki	300	262	87.33%
Word+email	252	210	83.33%
Google Docs	249	206	81.73%
Office Live	201	156	77.61%

Because students are less familiar with Twiki, Office Live and Google Docs than with MS Word, detailed written instructions, as well as demonstrations, were given to students on the use of Twiki, Office Live, and Google Docs. The instructions were given as part of the regular classroom teaching routine.

The collaboration project used for the research was a group research paper where students in groups of three were asked to find and describe an emerging and/or disruptive information technology that would provide some competitive advantage to a fictitious company. The company varied by semester and included a small manufacturing firm (making wooden pallets), a regional hotel chain, and a small specialized retailer (selling snowboards and accessories). All students taking the course in one semester were given the same assignment regardless of the section or technology they were assigned. The core part of the assignment was for students to apply the value chain model as well as Porter's Five Forces Model to determine the technology's effects on the firm. Completed papers were typically 1,200 to 1,500 words in length. On average, each student worked with the document about three times before submission.

Group membership was determined randomly by the instructor. Students were asked to avoid face-to-face meetings and were not given time in class to work on or coordinate the project. This was done to force students to experience how projects are conducted in organizations where participants may not see each other and often live in different time zones, making real-time communication difficult. The varied schedules of students helped to make it naturally difficult for them to schedule real-time meetings.

To ensure that students worked seriously on the assignment, the paper was a significant part of a student's overall course grade (approximately 20%). To avoid differences between treatment groups, the weighting of the grade was similar across sections and instructors.

After the paper was turned in at the end of the semester, students were asked to fill out a web-based survey about their experience with the project. Students were given a small number of extra credit points to complete the survey. This resulted in a very high response rate, but because students were given the extra credit only after the project was graded and were clearly instructed that the specific answers given would in no way affect their grade, this should not affect the specific answers to questions. To reinforce this, students were given clear guarantees that their instructor would not be able to see their answers to any of the questions.

The online survey asked detailed questions about the participants' experience with collaboration on the project. The survey was based on the instrument developed by Dishaw and Strong (1999) to integrate the Technology Acceptance Model (TAM) with Task-Technology Fit (TTF) concepts. The wording in the survey was adapted to fit the technology used in this study and task at hand (Appendix A includes the entire survey). The survey results were anonymous, but students were sent individual links, allowing the survey tool to keep track of which students had completed the survey in order to facilitate awarding extra credit points and sending reminders to complete the survey.

While analyzing the results, incomplete surveys were discarded. The survey was relatively quick to complete, with the median time to take the survey being 17 minutes and 18 seconds for completed responses.

To assess the role of Tool Experience on the results, subjects were surveyed on their experience and familiarity with each of the tools during one semester. The survey questions and scale are included in Appendix A.

Results

Task and technology were controlled in the first version of this experiment. However, instructors differed, which could have had a confounding effect. An analysis using ANOVA found that results were the same when examined by professor as when all data was combined. Therefore, we chose to present a combined analysis of all three instructors.

Construct Measurement and Validity

The research examines the impact of technology on fit with a collaborative writing and editing task. Four variables from the research model (Task-Technology Fit, Perceived Ease of Use, Perceived Usefulness, and Perceived Effort of Collaboration) are measured and statistically analyzed to understand this impact. Perceived Ease of Use and Perceived Usefulness are measured as single constructs. Perceived Effort of Collaboration is measured as a set of two constructs: Perceived Effort of Face-to-Face Collaboration and Perceived Effort of Distributed Collaboration. Likewise, Task-Technology Fit is indirectly measured as interaction between task characteristics and technology functionality (Dishaw & Strong, 1999). The Task Characteristics variable was represented using three constructs from Dishaw and Strong (1999): Knowledge, Plan, and Work. Knowledge is defined in terms of the perceived effort in examining and evaluating the work that was done. Plan is defined in terms of the perceived effort in determining the work that needed to be done and how to do it. Finally, Work is defined as the actual completion of work on the project. Technology Functionality is defined as the perceived support of the technology for tasks associated with creating and editing a paper. These four constructs represent the interaction of the three task characteristics - Knowledge, Plan and Work - and technology characteristics (Tech).

The constructs were measured based on the subjects' responses to a set of questions on the survey used to collect data. Each question was answered on a 7-point Likert scale (See Appendix B for the survey). The responses for each question that made up the construct were averaged by subject to provide a single construct measurement for the subject. To calculate Task-Technology Fit, the mean for the Technology construct was multiplied by the mean of each of the other three constructs that make up fit: Knowledge, Plan, and Work. The survey items that were used for each construct are included in Appendix A. Although the survey was previously validated, construct reliability was assessed in this research. Cronbach's Alpha is reported in Table 3 and shows that the construct measurements are reasonably reliable.

Table 3. Cronbach's Alpha results showing that the construct measurements are reasonably reliable

Construct	**Cronbach's Alpha**
Perceived Ease of Use	0.920
Perceived Usefulness	0.941
Perceived Effort of Collaboration:	
• Perceived Effort of Face-to-Face Collaboration	0.946
• Perceived Effort of Distributed Collaboration	0.836
Task-Technology Fit:	
• Knowledge	0.703
• Work	0.657
• Plan	0.537
• Tech	0.772

Statistical Tests

Hypothesis testing was performed via one-way ANOVA to test for significant differences in the variable means. Descriptive statistics for the variables are presented in Table 4. The results of ANOVA are presented in Table 5. Higher means indicate better fit, usefulness, ease of use, and effort of collaboration. The ANOVA results find statistically significant differences in all the variable means, suggesting that there is a difference in the four technologies tested in terms of Task-Technology Fit, ease of use, usefulness and required effort of collaboration.

Evaluation of Hypotheses

Hypothesis 1 postulated that there was no difference in the Task-Technology Fit of the four technologies. Analysis finds that Word/email and Google Docs had a statistically significant higher mean than that of Wiki and Office Live on the Task-Technology Fit variables Work, Planning, and Knowledge, indicating that Word/email and Google Docs were a better fit to the collaborative writing task. However, Google Docs and Word/email were not statistically different from each other. Hypothesis 1 is partially rejected.

Table 4. Descriptive statistics

		N	Mean	Std. Deviation	Std. Error
Work	Wiki	261	30.9418	10.21606	0.63236
	MS Word/email	200	**36.7950**	9.82506	0.69474
	Google Docs	206	**36.4595**	9.65583	0.67275
	Office Live	157	30.6045	9.07533	0.72429
	Total	824	33.6776	10.17951	0.35462
	Model Fixed Effects			9.77223	0.34043
	Random Effects				1.71422
Planning	Wiki	261	29.3406	9.64606	0.59708
	MS Word/email	200	**34.6670**	9.14928	0.64695
	Google Docs	206	**34.0963**	8.93868	0.62279
	Office Live	157	28.8341	9.02998	0.72067
	Total	824	31.7258	9.58656	0.33396
	Model Fixed Effects			9.23607	0.32175
	Random Effects				1.54764
Knowledge	Wiki	261	27.9902	8.69941	0.53848
	MS Word/email	200	**31.6420**	8.08545	0.57173
	Google Docs	206	**31.0993**	7.80012	0.54346
	Office Live	157	28.2786	8.31419	0.66354
	Total	824	29.7088	8.40791	0.29290
	Model Fixed Effects			8.25969	0.28774
	Random Effects				0.97001
Perceived Useful-ness	Wiki	260	4.9581	1.70468	0.10572
	MS Word/email	200	**6.5487***	1.23593	0.08739
	Google Docs	206	**6.1108**	1.51711	0.10570
	Office Live	156	5.1479	1.57101	0.12578
	Total	822	5.6700	1.66637	0.05812
	Model Fixed Effects			1.52846	0.05331
	Random Effects				0.39486
Perceived Ease of Use	Wiki	260	5.0923	1.65544	0.10267
	MS Word/email	200	**6.5300***	1.30206	0.09207
	Google Docs	206	**6.0825**	1.39616	0.09727
	Office Live	156	5.2051	1.68377	0.13481
	Total	822	5.7117	1.63258	0.05694
	Model Fixed Effects			1.51851	0.05296
	Random Effects				0.35733
Perceived Effort of Face to Face Col-laboration	Wiki	260	4.7250	2.47855	0.15371
	MS Word/email	200	**5.0150**	2.51773	0.17803
	Google Docs	205	4.4317	2.43850	0.17031
	Office Live	155	3.7097	2.02811	0.16290
	Total	820	4.5305	2.43655	0.08509
	Model Fixed Effects			2.39971	0.08380
	Random Effects				0.26266
Perceived Effort of Distributed Collabo-ration	Wiki	261	5.1552	2.04042	0.12630
	MS Word/email	200	5.4300	2.08430	0.14738
	Google Docs	205	5.1024	2.51500	0.17566
	Office Live	155	**6.9419**	.92399	0.07422
	Total	821	5.5463	2.13956	0.07467
	Model Fixed Effects			2.03061	0.07087
	Random Effects				0.40390

Table 5. ANOVA results

		Sum of Squares	df	Mean Square	F	*p*
Work	Between Groups	6974.099	3	2324.700	24.343	0.000
	Within Groups	78307.079	820	95.496		
	Total	85281.178	823			
Planning	Between Groups	5685.405	3	1895.135	22.216	0.000
	Within Groups	69950.094	820	85.305		
	Total	75635.500	823			
Knowledge	Between Groups	2237.796	3	745.932	10.934	0.000
	Within Groups	55942.469	820	68.223		
	Total	58180.266	823			
Perceived Usefulness	Between Groups	368.752	3	122.917	52.615	0.000
	Within Groups	1910.992	818	2.336		
	Total	2279.744	821			
Perceived Ease of Use	Between Groups	302.030	3	100.677	43.661	0.000
	Within Groups	1886.193	818	2.306		
	Total	2188.223	821			
Perceived Effort of Face to Face Collaboration	Between Groups	163.216	3	54.405	9.448	0.000
	Within Groups	4699.022	816	5.759		
	Total	4862.238	819			
Perceived Effort of Distributed Collaboration	Between Groups	384.929	3	128.310	31.118	0.000
	Within Groups	3368.812	817	4.123		
	Total	3753.741	820			

Hypothesis 2 postulated that there was no difference in the perceived usefulness between the four technologies. Analysis finds that Word/email has a statistically higher mean than any of the other technologies, indicating that it was perceived to be more useful at the task. Further, the Google Docs mean for perceived usefulness was statistically higher than that of Office Live and Wiki. However, there was no statistically significant difference between Office Live and Wiki. Hypothesis 2 is largely rejected.

Hypothesis 3 postulated that there was no difference in perceived ease of use between the four technologies. Analysis finds that Word/email has a statistically higher mean than any of the other technologies, indicating that it was perceived to be easier to use for the collaborative writing task than the other technologies. Again, the Google Docs mean was statistically higher than that of Office Live and Wiki. However, there was no statistically significant difference between Office Live and Wiki. Hypothesis 3 is largely rejected.

Hypothesis 4 postulated that there was no difference in the perceived effort of collaboration between the four technologies. The results are interesting. For perceived effort of face-to-face collaboration, subjects using Word/email had a statistically significant higher mean than subjects using Google Docs and Office Live, indicating that they perceived doing more face-to-face collaboration than subjects using these two technologies. They did not perceive that they did more face-to-face collaboration than subjects using Wiki. On the other hand, for perceived effort of distributed collaboration, subjects using Office Live had a statistically significant higher mean than subjects using any of the other technologies, indicating that they perceived more effort in distributed collaboration than subjects using these other technologies. There were no statistically significant differences in perceived effort of distributed collaboration between Word/email, Google Docs or Twiki. Hypothesis 4 is partially rejected.

The experience survey results are included in Table 6. These results show that students had significantly more experience with Microsoft Word than they did with any other technology. Google Docs was a distant second. Students who used MS Word found it easier to use compared to students who used other technologies. However, students assigned to Google Docs reported that this tool was the most useful for a writing and editing task requiring collaboration among several students. The school doesn't offer a class to teach students any particular technology. However, the university does have a Google Apps subscription.

Table 6. Results from experience survey N = 73

Question		**Mean**
How frequently have you used a wiki to create or edit text? (1-7)		1.39
How familiar are you with wikis? (1-8)		3.11
How frequently have you used Google Docs to create or edit documents? (1-7)		2.67
How familiar are you with Google Docs? (1-8)		3.73
How frequently have you used Microsoft Office Live to create or edit documents? (1-7)		1.43
How familiar are you with Microsoft Office Live? (1-8)		2.13
How frequently have you used Microsoft Word to create or edit documents? (1-7)		6.31
How familiar are you with Microsoft Word? (1-8)		5.63
Please rank the technologies in terms of how easy the software is to use. Type 1 for the easiest to use, 2 for second easiest, etc. Type '0' if you don't know or haven't used a technology.	# zero (0) Answers	Rating
Wiki	27	2.81
Google Docs	9	2.11
Microsoft Office Live	35	3.31
Microsoft Word	0	1.14
Please rank the technologies in terms of how useful the technology is for creating and editing a paper with 3-4 people in a group. Type 1 for the most useful, 2 for second most useful, etc. Type '0' if you don't know or haven't used a technology.	# zero (0) Answers	Rank
Wiki	30	3.10
Google Docs	8	1.29
Microsoft Office Live	35	2.88
Microsoft Word - documents exchanged over email	0	2.01

Discussion

The results are interesting. Task-technology fit was determined to be essentially the same for Word/email and Google Docs and significantly higher than for either Twiki or Office Live, even though on many of the dimensions identified in this study they differ more from each other than they differ from the other two technologies. For example, MS Word and Office Live are much closer to each other in editor quality/richness than MS Word and Google Docs are. Likewise, Google Docs and Twiki are much closer in integrating editing and collaboration tools and in document location than MS Word and Google Docs are. Closer examination suggests that the characteristics of collaborative process support and editor quality have a significant and potentially compensatory impact on fit. The high quality of the editor in the MS Word/email technology compensated for its relatively low support for the collaborative process, and the relatively high support of the collaborative process in Google Docs compensated for the lower quality of the editor.

Wiki did not perform well enough in these categories to be perceived to fit the task well. Office Live, on the other hand, combines the strong editing experience of Word with built-in support for collaboration, and therefore we expected this combination to be the best of both worlds and to fit the task exceptionally well. However, the results showed the opposite; Office Live was rated lower than both Word/email and Google Docs. Because the editor is the same as in the Word/email combination, the explanation for this finding must be found elsewhere.

Office Live and the Uncanny Valley of Collaborative Tools

The collaborative interface in Office Live is a web interface used to set up the collaborators for the document. Although it is possible to edit the document through a web interface, students were encouraged to do the editing through Word to take advantage of important features like "Tracking." So, after the collaboration is set up, the web interface was likely not used much. We, therefore, don't expect that the interface to control collaboration is the source of the differences seen in the results.

When examining the results from the experience survey, Office Live is clearly not very familiar to users. However, because Word is the primary tool used in Office Live, and this is a tool that students clearly have experience with, the lack of experience doesn't explain the difference either.

However, the experience of Word also includes understanding where documents are located and how they are handled. Although Office Live uses Word as its editor, the documents are stored centrally, and the user no longer has to manage documents as files. However, changes made by a user are not visible to another concurrent user until the document is "saved" by both, leading to potential confusion for inexperienced users on the mental model of where the document is stored and what the latest version is, potentially prompting the user to save a local copy. Users are asked to trust that the file handling happens in the background. This effect may be akin to the Uncanny Valley effect experienced in computer graphics and robotics where a human's positive response to a humanoid drops off dramatically if that humanoid is very close to being lifelike yet not quite close enough (Mori, 1970). The Word interface in Office Live is almost identical to the regular interface. The only difference is that the Save button has been replaced with a Refresh button whose functionality is very different from Word's (**Figure 5**). When saving in Word, the document on the screen simply gets stored to the file, whereas the refresh in Office Live saves the document and also pulls the changes made by other collaborators and shows those on the screen. This likely causes confusion for the user.

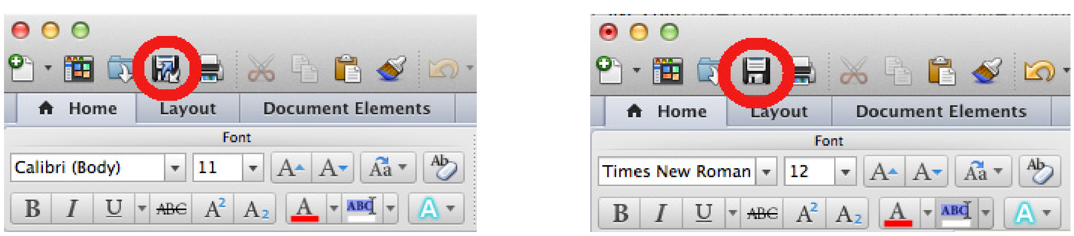

Figure 5. Difference in user interface between Word (right) and Office Live document in Word (left)

Rienzo and Han (2009) found that students preferred the writing and editing capabilities and familiarity of Office Live to Google Docs, but preferred Google Docs' real-time editing capability to Office Live's. This supports the notion that the issue is not with the editing capability, but with the mental model of either collaboration, the location of the document, or both. When using

Word/email, the process of collaboration may be cumbersome, but the process is familiar and it is obvious what is going on. In Office Live, the collaboration process is more obscure. It requires setting up collaboration on a website, and then the collaboration happens only through the Save/Refresh button.

Differences in Ease of Use and Usefulness

The result that perceived ease of use and perceived usefulness were significantly higher for MS Word/email and Google Docs is not surprising, given that they scored higher on Task-Technology Fit, which the TAM/TTF model predicts would be the case (**Figure 2**). However, the MS Word/email technology also scored significantly higher on perceived ease of use and perceived usefulness than Google Docs although there was no significant difference between them in Task-Technology Fit. This suggests that although the collaborative process support provided by Google Docs was significant enough to compensate for the quality of the editor with respect to fit to the task, the higher quality of editor in MS Word/email led subjects to perceive that MS Word/email was both easier to use and more useful. This is potentially enhanced by the possibility that students in this study spent more time on the individual writing/editing portion of the task than they did on the collaboration portion.

Tool experience may offer an additional explanation for the results associated with perceived ease of use and perceived usefulness. The TAM/TTF model (**Figure 1**) predicts that tool experience will impact these two variables as well as tool functionality and Task-Technology Fit. The results of the experience survey found that students had significantly more experience and proficiency with MS Word than any of the other technologies. Google Docs was a distant second to MS Word and much closer to Twiki and Office Live than MS Word. Further, students are very familiar with exchanging documents using email. These results explain why MS Word/email was perceived to be significantly easier to use and more useful than any of the other technologies: the subjects had much more experience with the tool that drove these perceptions. The survey also lends support to the compensatory explanation of the TTF variables. Google Docs was rated as the most useful for working in a collaborative environment.

Evaluating eCollaboration Challenges

The e-collaboration challenges identified by Nosek and McManus (2008) were identified as potential explanations for the differences between Twiki and MS Word/email found in our previous study (Dishaw et al., 2011). The results of this study provide insight into which of these e-collaboration challenges best explain the differences in Task-Technology Fit found among the four technologies studied. The challenge of the cognitive model of how group processes are carried out is likely rejected as an explanation. Google Docs and MS Word/email enable significantly different group process models, yet there was no difference in the Task-Technology Fit of the technologies. Collaborators appear to be able to adapt the process to fit the tool. The conceptual challenges that affect what individuals conceive of doing with the technology are a potential explanation. The mental model developed by students of performing a collaborative writing and editing task may be at odds with the mental model required to perform the tasks with the different technologies. The different characteristics of each technology require a different model of how the task is performed. This model likely includes components associated with the writing and editing part of the task and components associated with collaborating. Students have significant experience using word processing to write papers, resulting in a mental model that fits MS Words editor. They also have experience using email and other messaging tools, resulting in a mental model that fits both MS Word/email collaboration and Google Docs collaboration. However, Twiki's editing interface likely does not fit well with the writing/editing mental model, and Office Live's collaboration process does not fit well with the email/messaging mental model. Finally, technical challenges are not likely to be an explanation. All subjects were able to use the tools to effectively complete the task.

Implications for Pedagogy

Educators have a wide variety of viable tools available for students to write papers collaboratively. However, because student experience and familiarity with the tool plays a significant role in their perception of the tool, adequate training on the use of unfamiliar tools is important for effective use by students. A student group that is required to use a wiki, for example, might create the document in a familiar tool like MS Word and exchange it by email before a designated member of the group uploads it into the wiki, completely missing potential benefits. Caution should also be exercised in selecting tools that that have the look and feel of familiar tools, but work differently in certain areas. Students' prior experience and mental model of using a technology could contribute to confusion on using such tools. Research findings and others' experience are valuable resources and should be used in making the decision.

Implications and Future Directions for Research

Implications for conducting research are limited at this time. Possibly the most important lesson for conducting research on technology is to attempt to ensure that the way a technology functions matches the subject's perception of how it works. In the case of this study, we assumed that Office Live would outperform the others because subjects had experience with Word's high quality editor and the tool supported collaboration directly. The fact that the technology appeared to work like they originally expected, but didn't actually work that way, made the technology a very bad experience for the users.

The authors are beginning another similar study in which subjects will be given the ability to choose the technology for collaboration. Their experience with the various tool choices will be measured prior to selection and the reasons for their selection and their experience with the technology will be collected after concluding the task in addition to the Task-Technology Fit data collected in this study. This research will attempt to understand the factors that contribute to technology selection and whether the outcome matched their initial expectations.

Another future study will aim to develop an ability to predict the choice of technology based on technology characteristics and user attributes. Future research could also examine the "Uncanny Valley" phenomenon in more detail. Questions such as how much difference contributes to the mental model conclusion may help designers think carefully about the impact of upgrades or changes to software. Along these same lines, the technological characteristics that specifically impact the "Uncanny Valley" phenomenon should be investigated. We offer a first cut at this with the dimensions of the collaborative tools used in this study (see **Figure 4** and **Table 1**). However, at this stage these dimensions are primarily speculative. The extent of each dimension's impact on the outcome is not understood, and in some cases, the dimensions themselves need much further development.

Limitations

This study has limitations. First, the study uses three person groups of students. The limited size of the group may have favored one type of collaborative process over another thus favoring the tool that best supported that process. Also, as with all studies on students, the characteristics of the subjects may not make the study applicable to the business world. Additionally, the task of document creation and editing may not be applicable to other types of collaborative work. Experience with the tool may also be another confounding factor. As described in the Research Design and Methodology section, each group was assigned a tool. Students did not have a choice. However, as Table 6 shows, experience was very different between the technologies thus potentially favoring one tool over another in the outcome measures of Task-Technology Fit.

Conclusion

Taken as a whole, these results suggest that certain characteristics of the collaborative tools can have a significant impact on the effectiveness of the tool. A powerful interface with which the user has some experience is necessary, and support for distributed collaboration can be the distinguishing factor in making a tool an effective collaborative writing and editing technology. Additionally it is very important that the mechanics of how the tool enables the collaboration matches the user's mental model of how it is doing it. Our studies suggest that Word/email and Google Docs outperform Twiki and Office Live due to tool experience and superior Task-Technology Fit that may be due to the sophistication of the writing and editing tool, support for collaboration, and the clarity of the collaboration process. Office Live performs poorly because it looks similar to MS Word but the collaborative functionality works in an unexpected way for the users.

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Appendix A

Construct Items

Knowledge Construct Items

- I obtained information about changes to the document from data in the document itself.
- I made extensive use of my knowledge of the software with which the document was created.
- If I needed information to solve a problem, I knew where to look or who to ask.
- I asked someone for technical information about the designated software during this project.
- I consulted manuals to obtain information regarding Windows Operating System.
- I consulted manuals to obtain information about the software.
- I examined the document to obtain clues as to the quality of the paper.
- I obtained information about the paper being produced through examining the document.
- I learned a great deal about the topic of the paper by mentally processing the information provided in the document.
- I frequently consulted the software documentation.
- I learned a great deal about the topic by using the designated software tool.
- I had to weigh and evaluate a large volume of information about the document I was creating/editing.
- I had difficulty deciding which source of information to employ in attempting to solve a particular problem.

Plan Construct Items

- I had no difficulty in editing/changing the document.
- I did not have difficulty in figuring out how to create/edit the group paper.
- I frequently re-evaluated my plan of action with regard to completing the project.
- I had a number of choices to make regarding which source of information to consult in order to solve a particular problem.
- I frequently had alternative approaches to writing the document.

Work Construct Items

- I frequently made changes to the document in order to get feedback from other group members.
- I revised the document.
- I often evaluated other group members' changes to the document.
- I read the document and made additional changes as a result of my reading.

Distributed Collaboration Effort Construct

- I frequently e-mailed/text messaged my group to work on this document.
- I frequently e-mailed/text messaged my group to discuss this document.

Face to Face Collaboration Effort Construct

- I frequently met my group face to face to work on this document.
- I frequently met my group face to face to discuss this document.

Ease of Use Construct Items

- I found it easy to get the designated software to do what I wanted it to do.
- My interaction with the designated software was clear and understandable.
- I found the designated software to be flexible to interact with.
- I found the designated software easy to use.

Usefulness Construct Items

- Using the designated software enabled me to accomplish my tasks more quickly.
- Using the designated software enabled me to improve my performance on this project.
- Using the designated software increased my productivity on this project.
- Using the designated software enabled me to enhance my effectiveness on this project.
- Using the designated software made it easier to complete this project.
- I found the designated software useful in this project.

Technology Construct Items

To what extent did the software environment available to you supply the following functions?

- Create and write text.
- Edit existing text.
- Share a text document among individuals.
- Track changes in the text document.
- Identify the source of changes in the text document.

Appendix B

How frequently have you used a wiki to create or edit text? (1-7)
How familiar are you with wikis? (1-8)
How frequently have you used Google Docs to create or edit documents? (1-7)
How familiar are you with Google Docs? (1-8)
How frequently have you used Microsoft Office Live to create or edit documents? (1-7)
How familiar are you with Microsoft Office Live? (1-8)
How frequently have you used Microsoft Word to create or edit documents? (1-7)
How familiar are you with Microsoft Word? (1-8)
Please rank the technologies in terms of how easy the software is to use. Type 1 for the easiest to use, 2 for second easiest, etc. Type '0' if you don't know or haven't used a technology.
Wiki
Google Docs
Microsoft Office Live
Microsoft Word
Please rank the technologies in terms of how useful the technology is for creating and editing a paper with 3-4 people in a group. Type 1 for the most useful, 2 for second most useful, etc. Type '0' if you don't know or haven't used a technology.
Wiki
Google Docs
Microsoft Office Live
Microsoft Word - documents exchanged over email

Questions for experience survey.

Scale for “How Frequently have you used…

1. Never
2. Only a couple of times
3. once a month
4. 2-3 times per month
5. once a week
6. 2-3 times per week
7. daily

Scale for “How familiar are you with …”

1. Never heard of them
2. I have heard of them but don't really know what they are
3. I have heard of them but don't really know what they are
4. I know what they are
5. I know how to use them
6. I consider myself a proficient user
7. I consider myself an expert user
8. I and others consider me an expert

Biographies

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