DO PROTOTYPES HAMPER INNOVATIVE BEHAVIOR IN DEVELOPING IT-BASED SERVICES?

Research-in-Progress

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Abstract

In this paper, we explore how different forms of prototyping affect the innovation behavior of project teams. Prototyping is used to embody design hypotheses, which can then be quickly tested and refined. It is believed that this quick testing supports innovation, but we argue that only some forms of prototyping support innovation and others hamper it. Our research finds that it is predominantly low-fidelity prototyping that is likely to incite playfulness, which is a key antecedent to exploratory learning, the precursor to innovation. We use case studies as a first step in investigating how different forms of prototyping influence playfulness and subsequently, its effect on innovation. Our analysis of two software services projects lends support to the hypothesis that the extensive usage of IT-enabled prototypes hampers exploratory activities in contrast to low-fidelity paper prototypes. Overall this work suggests that prototype tool selection is an important element in fostering innovation.

Keywords: Prototyping, Innovation, Creativity, Case study/studies, Mixed methods
Introduction

Prototyping is a common exercise in the development of new products, primarily because it helps developers to better envision their ideas. As such, it can be expected to help significantly with the innovation process. Prototypes are models of a desired artifact and represent its essential characteristics, but not all characteristics are represented and those that are may only be implemented in a cursory fashion. Nonetheless, prototypes permit rapid and flexible development of product ideas at low cost because they can be readily modified (Floyd 1983; Pomberger et al. 1992). Uses made of prototyping are many and versatile. They include the elicitation of requirements, the improvement of communication between developers, and the evaluation of the new product’s usability and acceptance (Kordon and Luqi 2002). Since prototypes convey concepts and experiences, they are a valuable representation of knowledge (Schneider 1996), can be also used for the explication of an individual’s or a group’s tacit knowledge (Mascitelli 2000) and thus, can facilitate reflective thinking-by-doing activities (Hartmann et al. 2006; Schön 1983). Overall, the use of prototyping is especially valuable at the early stages of the innovation process in which the important characteristics of the final solution are yet unknown and people are confronted with a high level of ambiguity and uncertainty.

In these early innovation stages, playfulness is also important and has been shown to be beneficial (Liang-Hung et al. 2010) because it temporarily relaxes the insistence on purpose, consistency, and rationality (March 1982). Such playfulness allows experimentation but, at the same time, encourages rational decision-making (March 1982). Being playful reduces the fear of making mistakes and stimulates learning from errors (Glynn 1994). Thus, people are more willing to give their ideas a try and let failure provide valuable feedback allowing them to improve their ideas through this continuous learning (Thomke 2001).

Despite an extensive body of research regarding the benefits of prototyping and playfulness, existing literature provides no information on the relationship between prototyping and playfulness. There are disagreements about whether a prototype should be physical (using whiteboards, paper and pencil, post-its, Styrofoam forms, etc.) or IT-based (using representations on a computer screen) (Mascitelli 2000) as well as whether a prototype should be of low- or high-fidelity (Lim et al. 2006; Rudd et al. 1996). While research on playful learning has found that the use of tangible (physical) artifacts has a positive effect on the relationship between playfulness and learning (Price et al. 2003), others have also found that the use of a computer fosters playful behavior and thereby learning (Webster and Martocchio 1993). With regard to the degree of fidelity, some argue in favor of low-fidelity prototypes because of their rapid and low cost realization that allows fast build and review cycles (Carleton and Cockayne 2009; Lim et al. 2006). Others support using high-fidelity prototypes arguing that people do not evaluate an idea but its representation causing low-fidelity prototypes to be misunderstood and possibly rejected due to their inaccurate representation (Schrage 1999). Here, we find two conflicts. First, low-fidelity prototyping is likely to cause multiple cycles of innovation and thus, increase innovation. But low-fidelity prototyping may cause good ideas to be rejected because they are misunderstood and thus, decrease innovation. Second, prototyping that is physical may foster playfulness and thus, innovation, but computer-based prototyping is also likely to foster playfulness because of a computer’s responsiveness.

We propose that low-fidelity physical prototyping will create more innovation than low-fidelity computer prototyping because of the presence of significantly more playfulness with the tangible artifacts. We also propose that low-fidelity computer-based prototyping will create more innovation than its high-fidelity computer-based partner because the high-fidelity version’s technical demands and constraints will overwhelm the innovation process.

Our research examines the use of three different levels of prototyping systems (low-fidelity physical, low- and high-fidelity computer) during the innovation process of computer-based services and focuses on measuring how much playfulness the three types of prototyping systems generate.

The rest of this paper is organized as follows: the following section provides the theoretical background for our proposed research model, followed by a description of the research methodology we intend to use to validate our research model, and some initial findings from our case studies. We end by briefly stating the current status of our project and the expected findings of this research.
Theoretical Development

The primary use of a prototype is to model a desired artifact and represent its essential characteristics for testing and further development. Since only certain properties of the final solution are represented, it is cheaper, easier, and faster to build a prototype than the real artifact (Floyd 1983; Pomberger et al. 1992). Prototyping – the process of creating a prototype – includes the selection of the functions to be modeled, the development of the prototype, and cycles of demonstration, evaluation, and modification of the prototype (Floyd 1983). The main reason for building a prototype is to find out more about a problem or a solution to a problem (Davis 1992). Hence, prototypes are best considered as a learning tool to get a more precise idea about a possible solution. Thereby, the prototype functions as an embodiment of hypotheses which can be tested and further developed (Hartmann et al. 2006). Depending on the objective, different purposes are pursued with the development of a prototype. Frequently, prototypes are used for requirements elicitation and validation (Hickey and Dean 1998), to facilitate communication and feedback between different stakeholders (Floyd 1983), to evaluate interim results (Hoffmann and Leimeister 2011), to convey knowledge in the form of concepts and experiences (Schneider 1996) or to make explicate the tacit knowledge of individuals or a group (Mascitelli 2000), or a combination thereof (Kordon and Luqi 2002).

In the literature, a distinction is made between two fundamentally different approaches to prototyping: throwaway and evolutionary (Davis 1992; Floyd 1983; Pomberger et al. 1992). While in evolutionary prototyping the prototype evolves over time, and the final version of it becomes the product, throwaway prototypes are discarded after they have fulfilled their purpose (Davis 1992; Kordon and Luqi 2002). Throwaway prototyping can be further distinguished into exploratory prototyping, which emphasizes the elicitation of the required and desired features of the product as well as the discussion of alternative possibilities for the solution, and experimental prototyping, which focuses on determining the technical feasibility of a possible solution (Floyd 1983). At the early stages of the innovation process, only throwaway prototyping is reasonable, because at this stage the focus is on gaining new information about alternative possibilities, exploring different options and experimenting with the various properties of a possible solution (March 1991; Thomke 2003).

The fidelity of a prototype is a measure of the extent to which the prototype accurately represents the appearance and interaction of the final product (Rudd et al. 1996). Low-fidelity prototypes can be implemented rapidly, and cheaply (Rudd et al. 1996). Examples of physical low-fidelity prototypes are sketches and diagrams done either on a whiteboard or paper. Computer-based mockups are examples of IT-based low-fidelity prototypes. Due to their rapid low cost generation, low-fidelity prototypes allow fast and cheap build and review cycles which help to develop a shared understanding of the team's problem solution (Carleton and Cockayne 2009; Lim et al. 2006). However, people do not evaluate an idea but rather its representation (Schrage 1999). Thus, with low-fidelity prototypes only a small fraction of the actual product is considered in the evaluation which may cause proposed solutions to be rejected or misunderstood because of their inaccurate representations. High-fidelity prototypes, on the other hand, try to fake the visual appearance and functionality of the final product as accurately as possible (Lim et al. 2006). To achieve this, much effort is required which makes this type of prototyping time-consuming and expensive (Rudd et al. 1996). During the implementation of high-fidelity prototypes technical obstacles can appear, which cause additional effort in implementing the prototype (Hoffmann and Leimeister 2011) and draws the innovator's attentions away from a focus on innovation.

Innovation is an information-creation process (Nonaka and Kenney 1991) that starts with theoretical conception and ends with commercial exploitation of the invention (Trott 2008). Innovation activities can be distinct in terms of exploration and exploitation with respect to the kind of information created. Exploration is concerned with gaining information about new possibilities and is captured by terms like search, variation, experimentation, play, discovery, variation, flexibility, and risk taking (March 1991). The expected results are radical innovations. Exploitation, on the other hand, is concerned with the utilization and incremental improvement of existing possibilities and can be described by terms like refinement, efficiency, execution, and implementation (March 1991). In this case, the expected results are evolutionary innovations. At the early stages of design, activities focus on the creation of new information and the generation of ideas that challenge the status quo. The later design activities are concerned with exploitation, i.e., using available information to improve a design (March 1991).
Playfulness is a mind-set (Lieberman 1977) that is characterized by qualities like spontaneity, flexibility and creativity (Serenko and Turel 2007). Thus, playful behavior is not a set of activities but rather "[...] a set of qualities that is superimposed upon an activity regardless of its content." (Mainemelis and Ronson 2006). Playfulness leads to high involvement and provides immediate pleasure whereby people are intrinsically motivated, become absorbed in the creative process, evaluate information on the basis of its intrinsic characteristics (means) instead of its consequences (ends), work longer on finding an original solution and combine ideas in surprising and unexpected ways (Sandelands 1988; Schrage 1999; Starbuck and Webster 1991; Webster et al. 1993). Moreover, research has found a positive correlation between playfulness and innovation (Ekvall 1996; Liang-Hung et al. 2010; Mainemelis and Ronson 2006; Schrage 1999) with playfulness positively influencing exploratory learning; a crucial requirement in the development of radical innovations (March 1991).

Research on playfulness can be divided into three categories. One stream of research contributes to trait theory and defines playfulness as a characteristic of the individual which is stable over time (e.g. Glynn and Webster 1992). Another stream of research contributes to state theory and defines playfulness as a behavior pattern that depends on the situation (e.g. Webster et al. 1993). A third stream of research combines both viewpoints and suggests that playfulness is a stable prediction of human behavior but is influenced by the situation in which the construct is tested (Woszczynski et al. 2002). While playful traits are an important determinant for people’s disposition to engage in playful behavior, we adopt in our research the situation view of playfulness, because past research has demonstrated that IT, when manipulated appropriately, can encourage playfulness (Starbuck and Webster 1991; Webster et al. 1993).

Playfulness has been shown to have a positive effect on innovativeness (Ekvall 1996; Liang-Hung et al. 2010; Mainemelis and Ronson 2006; Schrage 1999) with playfulness influencing exploratory learning; a crucial requirement in the development of radical innovations (March 1991). Playfulness deliberately temporarily relaxes the rules in order to explore alternative possibilities allows experimentation but still encourages reason (March 1982). It affects creativity in a positive way (Baas et al. 2008), reduces the fear of making mistakes, and stimulates learning from errors (Glynn 1994).

However, the state of playfulness depends on the possibility to engage in playful activities, i.e. activities that create both immediate pleasure and involvement (Starbuck and Webster 1991). Related to the use of computers at work, IT has been found to have a positive influence on playfulness due to its quick response and ease of use (Webster and Martocchio 1992). But is this also true for the development and usage of prototypes in the innovation process? The kind of representation of ideas has a huge influence on the perception of the activities, in which people engage in during their development, testing and advancement: “How people behave around different versions of prototypes [...] influence[s] how value is created or destroyed.” (Schrage 1999). For instance, research shows that human perception and thus creativity are reflexively triggered by physical environments (Carleton and Cockayne 2009; Mascitelli 2000). This allows designers to think by doing rather than carefully thinking things through (Hartmann et al. 2006) and suggests that physically based prototypes enhance creativity. On the other hand, IT-based prototypes are regarded as more flexible and more efficient (Thomke 2001; Thomke and Fujimoto 2000). Such flexibility also enhances creativity.

**Proposed Research Model**

Based on our literature review, we hypothesize that IT reduces exploratory learning, because the development of high-fidelity IT-based prototypes leads to a low level of playfulness, and thus hampers such learning. In this respect, prototypes have a moderating effect on the relationship between playfulness and exploratory learning. Therefore, the research question is: How do different kinds of prototypes with varying levels of IT support and fidelity influence playfulness and thus exploratory learning in the development of IT-based services? Figure 1 represents our research model.
Figure 1. Proposed research model illustrating that paper-based prototypes will have a positive effect on playfulness and thus, innovation whereas high fidelity computer-based prototypes will have the opposite effect on playfulness and thus, innovation.

Research Methodology

We plan on using a multi-method research approach consisting of case study research and controlled laboratory experiments (Venkatesh et al. 2013). Our first effort was to conduct two in-depth case studies to determine if our hypothesized relation between playfulness and type of prototyping system has any validity. We then plan shorter case studies aimed at creating and refining methods for coding and measuring playful behavior during the early innovation stages of IT development. In a third step we will conduct experiments to examine how playfulness is related to type of prototyping employed.

For the initial stage of our research project, we observed two project teams, one using two and the other using three methods of prototyping. We observed them informally to gather insights into (a) whether our hypotheses regarding the impact of prototyping method on playfulness might have validity and (b) whether we could observe and measure playfulness. This observation phase of our research is nearly complete.

The two projects were commissioned by a German car manufacturer. The teams had the same contact persons at the company, and the projects followed the same design thinking approach (Vetterli et al. 2013). This approach is typically characterized by an iterative cycle consisting of three phases: (1) reformulate the problem, (2) make a change, and (3) evaluate the current state (Stacey and Eckert 2010). In this process, prototypes were used. At the beginning, low-resolution prototypes were employed for exploring the design space. As the project progressed, the resolution of the prototypes increased and the knowledge gained in the prior intensive learning phases converged into a final novel solution (Vetterli et al. 2013). The projects observed in this study followed a process that started with a design space exploration and then passed through six prototyping phases with different objectives. At each prototyping phase different rules and objectives were applied and the team was encouraged to think outside the box. Through these instructions, we attempted to create playful behavior and encourage the team members to explore novel solutions.

The composition of the teams, however, was different in the two projects. The first project was carried out by three students (two men and one woman) who were all enrolled in the master degree program Information, Media and Technology Management at a university in Switzerland. The second project was carried out by a more diverse group of students consisting of seven students (six men and one woman). Three of them were enrolled in the same degree program as the students of the first project. Half of the other four students were studying Mechatronics and the other half Management Engineering at a university in Italy. Each of the projects lasted ten months. The first project started in September 2010 and ended in June 2011. The second project started in September 2011 and ended in June 2012. The first project was about the development of novel solutions for mobility services, i.e., IT-based services that use the connectivity function of a car for data exchange between car and infrastructure or car and other devices in order to improve the customer experience while traveling. The second project was also instructed to develop a novel mobility service. However, while the first team had a very broad and unrestricted design space, the second team was asked to develop a community service that provided an added value for the customer, created a lock-in effect for the customer, and generated additional valuable information for the company. In the second project, the students also had the explicit goal of developing an executable prototype for their IT-based service.

We collected the following data from the two teams: (1) our impressions from meeting with the teams
regularly and observing their interactions, their design ideas and their difficulties; (2) team project documentation for each prototype created which included a design rationale, the results of user testing and the learning that occurred from the testing; and (3) a final project presentation and a final report. The 2010 Team used two prototyping techniques, paper-based mockups and low-fidelity computer prototyping. The 2011 Team used high-fidelity prototyping in addition to the techniques used by the 2010 Team. Both teams did exceedingly well on their projects and arrived at creative solutions in the judgments of the automotive company that commissioned the projects and the three instructors guiding the teams. We noted that both teams acted in an exceedingly playful manner when engaging in design with paper-based prototyping, and that this playfulness gradually disappeared as they moved to computer-based prototyping. We also noted that Team 2010 continued to replace design ideas with new ones and engage in playful behavior longer than Team 2011 which began to focus on generating a high-fidelity prototype. The design replacement behavior conforms with what is already known about low- and high-fidelity prototyping, that is, the relative ease of developing an idea makes it easier to discard a prior one (Carleton and Cockayne 2009; Lim et al. 2006).

One of the key problems we face in conducting our research is operationalizing a measure for situational playfulness. Much of the current research on playfulness is based on trait measurements (Glynn and Webster, 1992) or recall that is obtained by a validated survey instrument (Woszczynski et al. 2002). Both approaches have problems in measuring what we are trying to observe. First, trait measurement is really a measurement of a trait possessed by an individual. We are looking to measure the behavior of a group in a particular situation. The trait measure can be useful as a control variable because a person with the trait of high playfulness is more likely to engage in playful behavior in-group interactions. Second, also the fact recall of an affective behavior can be used as a validity check on our situational measures, although such a measure has its own validity issues since individuals are more likely to recall the last five minutes of a one hour meeting rather than its entirety.

Initial Findings

We noted in our observations that key behavior patterns existed that we would characterize as playful. We also noted that many of these patterns could be categorized by the traits measured by Glynn and Webster (1992) and that they could be readily observed as definable units of behavior. This suggests that we can measure situational playfulness through coded behavior and that we can relate the coding validity to existing frameworks that have been developed. We also observed that significantly more playfulness occurred in both groups with the paper-based prototyping system and that the playfulness ended as soon as computer prototyping began. Finally, since other research has demonstrated that playfulness leads to innovation (Glynn 1994) we noted many ideas being put forth, tried out and then discarded with the advent of a replacement idea. We noted this both in the student documentation and in our observations. This suggests that exploratory learning / innovation is readily measurable by counts although labeling the importance and significance of each idea may be difficult.

Our initial study has serious limitations at this point. The groups were ill-formed in that one was significantly larger than the other and the groups had different gender mixes. We did not measure playfulness traits in any of the group members which may have affected their tendency to engage in playful behavior. Also, since there is significant uncertainty at the start of a project, it is possible that this uncertainty alone created playful behavior. These issues are serious, but the initial study has suggested that we can (1) measure situational playfulness, (2) control our group formation to control for the playfulness trait and (3) create groups that effectively control for type of prototype mechanisms employed by the groups.

Current Status of the Project and Expected Findings

Our next step is to run shorter development projects (of approximately one week’s duration) using paper-based prototyping and ideation techniques (Schrage 1999) which we will videotape and code for playfulness and exploratory learning / innovation. Once we obtain reasonable coding scores for both variables, we will then develop an experiment which will test the impact of different prototyping techniques on playfulness and exploratory learning / innovation. For this next study, we will run a set of
four teams that will be assigned prototyping tools at different stages of the team’s development. In this study, we will again measure exploratory learning and playfulness using the coding developed earlier. We believe that this research will be valuable to both researchers and practitioners as it will not only provide empirical evidence regarding the purposeful use of prototypes but also shed new light on how to manage the early stages of the software development process.

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References


