TEST OF A BOUNDARY OBJECT FOR PROCESS IMPROVEMENT

INTRODUCTION

One of the primary ways organizations respond to dynamic environments is by solving internal problems related to sources of competitive advantage such as developing new products, introducing new technologies, and improving work processes. Often such problem solving entails interacting with individuals from different functional departments. A significant body of literature acknowledges that problem solving involving multiple departments is challenging and difficult because knowledge, which is central to effective problem solving, seems to travel with greater difficulty across departments than within departments (Brown & Duguid, 1998; Carlile, 2002, 2004; Pfeffer & Sutton, 1999; Soo et al., 2002; Szulanski, 1996).

Many scholars are convinced that boundary objects (BOs) can play a key facilitating role in inter-departmental problem solving. BOs are physical artifacts that provide a common language and promote shared understanding about a problem or a situation among a group of individuals to reach a mutually satisfactory resolution. For example, a medical chart in a hospital is a physical artifact usually presented in a standardized format that serves as a BO. Physicians from different functional disciplines read the chart, record information, and discuss among themselves the best possible treatment for the patient.

Much of the existing research on BOs examines their use in problem solving contexts such as new product design and development (e.g., Bechky, 2003; Carlile, 2002, 2004; Henderson, 1991, 1995). Since new product development (NPD) is a multi-disciplinary exercise, effective participation by everyone is essential to introduce a successful new product into the market. Thus BOs appear prominently in NPD process. However, little is known about the use of BOs in process improvement activities, even though process improvement often involves multiple disciplines.

In an effort to understand the role of BOs in process improvement activities, this research draws on the prior work on BOs by other scholars. Through largely qualitative research, scholars have found that an effective BO seems to possess certain key characteristics for cross-departmental problem solving. Our work with the A3 Report, a tool adapted from Toyota Motor Corporation to help in process improvement, suggests that it embodies the characteristics outlined in previous work. It also embodies an additional characteristic, not discussed in the literature, which seems relevant in the process improvement context. Using a field-based survey, we tested the predictive abilities of those characteristics to explain the efficacy of the A3 Report as a BO in process improvement.

In the next section, we provide some background information that motivated this research. Next, we present the literature review on the application of BOs in different problem solving environments and the hypotheses for the different characteristics to be tested. We then discuss the research methodology followed by our findings. Subsequently, we discuss the implications of our results, and conclude the paper with some final comments.

BACKGROUND

To better understand the efficacy of BOs in an inter-disciplinary work environment, the A3 Problem Solving Report, or succinctly the A3 Report, was adapted from Toyota Motor Corporation. The report is so named because it is encapsulated on one side of A3 size paper (metric equivalent of 11”×17”). The A3 Report template (Figure 1) guides the problem solver to follow the prescribed steps of a systematic problem solving process and document them. The left-hand side of the report involves “problem investigation” and the right-hand side involves “problem resolution.” The outline of the template is as follows:

1. Theme: Description of the problem being investigated.
2. Background: Information essential to understanding the problem and its importance.
3. Current Condition: A pictorial representation of the current process using iconic symbols. The pictorial representation is based on first-hand observation of the process currently experiencing difficulties. Alongside the diagram, problems are highlighted using storm clouds, and the magnitudes of the problems are quantified.
4. Cause Analysis: Results of the structured analysis to ascertain the root causes for the problems outlined in the storm clouds of the current condition.
5. Target Condition: A pictorial representation of the envisaged new process using iconic symbols, based on the understanding of the current state, the root causes, and the countermeasures to address the root causes.
6. Implementation Plan: The actions necessary to accomplish the target condition, the person responsible for each action, a target date for completing each action, and the anticipated outcome.
7. Follow-up: How and when the new process will be measured for improvement. Reasonable targets are established beforehand and the results of the new process are measured against the specified targets to assess the magnitude of the improvement.

Insert Figure 1 about here

The setting of this research was a mid-sized hospital in North America. The project was a collaborative undertaking between a state university and the hospital. The hospital's activities include obstetrics, pediatrics, rehabilitation, surgery, neonatal intensive care, nuclear medicine, emergency, cardiology, and general medical care. The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) accredits the facility. In the initial stages, individuals from various functional departments in the hospital were trained to use the A3 Report. Subsequently, the tool was tested in the cardiology department and later in the pharmacy department. As time progressed many individuals in the hospital were trained and became interested in using it, and the process improvement efforts propagated hospital-wide.

At a later stage, the first author joined the hospital as an action researcher and spent six months participating in multiple process improvement related problem solving exercises using the A3 Report. The problems addressed were strategically important to the leadership of the hospital. Members from patient financial services, hospital information management, registration, and emergency departments participated in such problem solving efforts. As he coached the individuals, he observed limited knowledge of the members beyond their own functional departments and that they had little understanding of how their performance impacted other departments. The departments did not seem to work towards a common purpose and so organization goals were often not met. Many processes were fraught with errors, rework, and wastes. While participating in the problem solving, he observed that the A3 Report not only provided a common language but also facilitated shared understanding among the individuals from these disparate departments. Individuals were able to discuss their differences, their interdependencies, and how lack of contextualized understanding inhibited satisfactory process performance. They negotiated agreed upon solutions to resolve the problems. The agreed upon solution motivated them to alter their pre-existing understanding, as some old knowledge was relinquished and some new knowledge was embraced to honor the collective solution. As they implemented the new process they were able to see the improved results, which further ossified their new knowledge. These field-based problem-solving efforts shaped the first author's understanding of A3 Report as a potential BO in process improvement activities.

LITERATURE REVIEW

The concept of BOs can be traced to the work of Star and Griesemer (1989). They use the example of a dead bird and demonstrate how individuals from different thought worlds use the same object for different purposes. The same dead bird had different meaning to the amateur bird watcher and the professional scientist. The scientist used the bird to shape his research goals while the amateur bird watcher planned to preserve the bird as a collection piece in a museum. Accordingly, they coordinated their activities to meet their individual goals.

Following Star and Griesemer's work, a number of researchers became interested in the concept and use of BOs in inter-departmental problem solving. For example, Berg and Bowker (1997) found that a patient's medical record can be an effective BO among different caregivers for planning interventions, coordination, and interaction in a healthcare setting. The same medical record became useful to the insurance companies, researchers, and government bodies for different purposes. Yakura (2002) investigated the role of a Gantt chart (visual artifact to represent a project timeline) as a temporal BO between an information technology (IT) consultant and its client, a public utility company, in managing the progress of an IT project. The Gantt chart became an effective temporal BO in interpretation and negotiation between the IT consultant and its client. In a different study, Patel, Branch, & Arocha (2002) argue that properly designed pharmaceutical labels can act as effective BOs and can avoid biases and errors in interpretation between the prescribers and the ultimate users of the medicine. More recently, Pawlowski and Robey (2004) report the use of shared information systems as BOs in integrating knowledge across functional departments and resolving organizational conflicts in a manufacturing setting.

Thus, BOs have been deployed in multiple problem solving contexts, but the context where BOs have been most studied over the last decade is new product design and development. Henderson (1991) contrasts the efficacy of two different BOs in the same organizational setting. She notes that hand sketches facilitated knowledge integration between designers and the shop floor personnel in designing a new turbine engine package. The designer hand sketched the product and sought input from the shop floor personnel, then modified the drawing accordingly. Thus, sketches provoked individual thinking and captured new knowledge, which resulted in collective new knowledge. The development of similar collective knowledge was impaired when CAD-CAM drawings were used. CAD-CAM generated images appeared so strongly structured in common use because of its interlocking devices with other computer databases that it lost its flexibility to change and became less effective for knowledge integration.

In a related study, Carlile (2002) investigated the role of different BOs in the development of new safety valves for a manufacturing firm. In particular, he observes that the assembly drawing became an effective BO for three reasons. First, it provided a common language for the stakeholders – the manufacturing engineering department and the design department. Second, it offered a concrete means to represent the work context and the associated concerns of the stakeholders. Finally, it provided a platform for knowledge transformation. As a consequence, the stakeholders were able to see key differences and interdependencies in their domain-specific knowledge, and how they affected the new product development process. This exchange of knowledge propelled them to reach an agreement by jointly transforming their domain-specific knowledge. Such joint knowledge transformation was not previously possible because the old assembly drawing reflected the concerns and the work contexts of the manufacturing department and not the concerns and the work context of the design department, and therefore, had limited impact on product development efforts. Interestingly, we observe in Carlile's research that both the design department and manufacturing department personnel had similar levels of training and expertise to understand drawings. Hence, the new version of assembly drawing became the common language for conversation to solve problems. However, when the training of individuals of different departments is different, drawings could become a roadblock in problem solving, as we observe in another study.

Bechky (2003), from her empirical research in a semiconductor equipment manufacturing company, finds tangible BOs, such as prototypes, to be more effective than drawings in creating common ground between two departments (design and assembly) because such objects invoke the necessary elements of work context. In fact, quite contrary to the general notion that engineering drawing is the best communication medium for cross-departmental knowledge interchange, Bechky reports that the assemblers found it too abstract to associate with their physical conceptualization of the product. The assemblers readily understood the machine in terms of the physical parts and their spatial relationships and not in terms of the conceptual language of the drawing, while the engineers only understood the product in the language of drawings. Thus, the engineering drawings failed to develop a common understanding to facilitate a meaningful conversation between the designer and the assembler toward solving problems in the new prototype development. Consequently, the designers used the prototype to tap into the domain-specific knowledge of the assemblers and facilitate knowledge integration to solve problems.

From these studies it appears that an appropriate BO in one setting can become a boundary roadblock in another setting, even when the problem solving contexts are very similar, i.e., producing a new product. Nonetheless, several important characteristics of an effective BO emerge from the review of the existing literature. First, it needs to accommodate the work context and be objective to represent the concerns of all stakeholders for meaningful participation (Carlile, 2002). Second, it should be loosely structured to promote individual creativity and communication for solving problems (Henderson, 1991). Finally, it should facilitate integration of different knowledge of individuals to develop a new collective knowledge to solve problems (Bechky, 2003; Carlile, 2002; Henderson, 1991). However, such characteristics emerged from qualitative research on specific problem types in a particular organizational setting. Therefore, it is unclear if some of the characteristics are indeed relevant in multiple problem solving contexts.

Process Improvement and Boundary Objects

Process improvement is also important to a firm's success and longevity, and often requires participation from diverse functional departments. Experts posit that the dynamic core competency of a firm depends on process related improvements that require close inter-relationships among key personnel in various functions (Lei, Hitt, & Bettis, 1996). In this respect, others have shown how Japanese companies such as Honda (MacDuffie, 1997) and Toyota (Adler, Goldoftas, & Levine, 1999; Spear & Bowen, 1999) have relentlessly pursued corporate-wide process improvement to ascend in the competitive car market. In fact, these high performing companies have always encouraged inter-departmental problem solving to share skills with each other to develop new products and processes. Furthermore, process improvement leads to the creation of new routines, which promotes acquisition of new knowledge and skills by organizational members, and helps develop and refine core competencies not easily imitable by competitors (Dosi, 1988; Lei et al., 1996). Some argue that continuous innovation in routines is needed for the creation of new skills for developing future products and process technologies (Henderson & Clark, 1990; Leonard-Barton, 1992). In sum, process improvement is critical to maintaining a competitive advantage in a turbulent and chaotic market place.

Even though process improvement is important, little empirical research exists on the use of BOs in process improvement related problem solving compared to the research in new product design and development. One possible explanation is that new product development is a favorite context for researchers interested in BOs because products are tangible objects, and the BOs used are likewise tangible. Therefore, problems and the tools used to solve such problems are well defined. For example, an engineering drawing is a two-dimensional pictorial representation of the actual physical product, with a one-to-one mapping between the two. Similarly, a prototype is almost an exact replica of the intended new product to be manufactured. Consequently, problem solving revolves around a tangible object. By seeing the product, members are able to invoke the necessary work context with ease and are able to discuss their specialized knowledge, their interdependencies, and work on a mutually agreeable solution. Therefore, such settings provide an ideal context to the researchers to investigate the role of BOs.

In contrast, the task of using a BO for improving a process is more difficult because processes are not as tangible as a physical product. Often, one cannot go somewhere to “see” the process. Traditional process maps comprising ellipses, diamonds, and rectangles are often used to represent a process, but they do not map onto the real process as closely, and therefore, members do not seem to connect to the work context easily to participate in a meaningful discussion. Henderson's (1998) study in a call center for a copy machine manufacturer is illustrates this contrast. The design engineers, while developing a new machine, sketched its parts on a scrap paper or in the margins of the drawings and the discussions among the members ensued. In contrast, process reengineers used pre-defined computerized templates for process improvement, which were somewhat inflexible, high-level abstractions of the process that became dysfunctional as BOs.

Process Improvement using Boundary Objects in Healthcare

Our understanding of a BO as a process improvement tool becomes even fuzzier in healthcare. Unlike manufacturing, most healthcare services are intangible, and many processes are electronically or manually driven and so are not easily observable, making processes in a healthcare context difficult to define. Furthermore, healthcare individuals often have conflicting goals (e.g., patient care versus process expediency), and therefore, often lack a common thread to serve as a starting point in solving a problem. Therefore, collaboration across functional disciplines seems difficult and challenging and the need for BOs becomes more pronounced to bridge the differences.

HYPOTHESES

To investigate the efficacy of BO in process improvement, the A3 Report was enacted as a tool to help individuals from different functional departments produce satisfactory improvements to work processes. In fact, the A3 Report seemed to possess the same key characteristics as enumerated by scholars in the literature on BO – providing objectivity, facilitating knowledge integrability, fostering creativity, and assisting communicability. Our initial observations at the research site suggested an additional characteristic – simplicity in use – not discussed in the literature, which may be relevant to the effectiveness of BO in process improvement. We observed that many employees at the research site did not have a college level education, yet their participation was essential for successful process improvement. Therefore, the complexity of a tool could impede effective participation by those individuals. From a BO perspective, the A3 Report is a simple tool to understand and write.

We measured the efficacy of the A3 Report as a BO in two dimensions. First, it can be described as effective only when the organizational members use it repeatedly. Second, it is effective when using it results in superior process outcomes. In an effort to answer the two questions of what characteristics of the A3 Report motivate repeat usage, and as a second step, what characteristics are reported to be essential for superior process outcomes, we framed the following hypotheses.

> The following characteristics of the A3 Report will be positively associated with tool usage (**H1**) and process improvement (**H2**):
> a. Objectivity
> b. Knowledge integrability
> c. Communicability
> d. Creativity
> e. Simplicity

RESEARCH METHODOLOGY

To test the hypotheses, we conducted a field survey in the hospital described in the background section. The target respondents for this study were individuals who had direct experience in writing the A3 Report, or were involved in problem solving using the report. The first author initially made a list of prospective respondents based on the information he received from different coaches involved in solving problems using the A3 Report. Subsequently, he sent an email to all employees in the hospital to make sure all individuals with A3 report writing experience had the opportunity to participate in the survey. While doing this exercise he also observed that a significant number of individuals with A3 Report writing experience had left the organization. Therefore, they could not be contacted.

Data Collection

A detailed survey instrument was used, which contained close-ended questions on the predictor and the criterion variables. In designing the instrument, we followed the guidelines provided by the literature (Aiman-Smith & Markham, 2004; Alreck and Settle, 2004). Prior to conducting the survey, the second author, a professor of Industrial Engineering with extensive experience in quantitative research, checked for content validity of the instrument. A number of hospital employees experienced in using the A3 Report also checked the questionnaire for the face validity. In order to counteract response bias, some of the questions were reverse worded. We created multiple metrics for each predictor variable to improve the reliability of the measures. The survey instrument was kept short to maximize the rate of response without diluting the survey objectives, and was coded for faster post-survey analysis. Because of the subjective nature of the data, the level of significance was set at 0.10 as suggested by Garsen (2002).

Prior to conducting the final survey, we conducted a pilot survey (N = 6) to check the reliability of the instrument and identify any ambiguities in the questionnaire. We had to content ourselves with a small sample for the pilot study due to the size of the respondent pool. We looked at the response pattern of those few individuals and also checked for any missing data.

No abnormal responses were observed to suggest that ambiguity in the questions existed. We calculated the Cronbach's alpha of the metrics for each variable and it varied approximately between 0.6 and 0.9. Two variables had Cronbach's alpha between 0.6 and 0.7, which is acceptable for new scales (Robinson, Shaver, & Wrightsman, 1991). We also ensured that correlation between variables was less than 0.65 to measure discriminant validity, i.e., the predictor variables were indeed different (Aiman-Smith & Markham, 2004).

The survey instrument was sent with a cover letter to 60 individuals in the hospital. They represented every level in the organizational hierarchy (directors, managers, supervisors, and front line staff). The cover letter guaranteed that their responses would be kept confidential. We received 56 responses indicating a response rate of 93%. The respondents included 11 males and 42 females (3 respondents did not disclose their gender). Individuals held a master's degree (N = 10), a bachelor's degree (N = 18), an associate degree (N = 10), a high school education (N = 16), or other degrees (N = 2). The respondents represented clinical departments (N = 31), fiscal and administration functions (N = 15), and ancillary and support functions (N = 10). Most of the respondents worked full time (N = 46) though some worked part time (N = 10).

Criterion Variables

A3 report usage. We measured the repeat usage of the A3 Report in terms of how many A3 Reports a respondent completed in the previous year. This measure was an objective account of the actual usage of the tool, and an indirect measure of the effectiveness of the A3 Report. In many cases, respondents wrote multiple A3 Reports, suggesting that they found it beneficial for improving work processes despite tight work schedules.

Process improvement. Process improvement (PI) is defined as the improvement in various process parameters (productivity, wasted time, number of errors, costs, patient care) as a result of problem solving, as reported by the respondents. We created six items to measure this construct based on the different process parameters used by the organization. We used a 3-point Likert scale fixed from 1 = worse to 3 = better. We also used a seventh item using a 5-point Likert scale anchored at 1 = strongly disagree and 5 = strongly agree for the construct. We added up the scores for seven items and averaged to get a composite score for the scale (Cronbach's alpha = 0.87). See the appendix for the items used in the scale.

Predictor Variables

We had five predictor variables of interest: objectivity, knowledge integrability, communicability, creativity, and simplicity. However, as the correlation between communicability and knowledge integrability was high ($r = 0.76$, $p < 0.05$) and appeared collinear, we did not use them together in the same regression model. The actual measures for each of the variables can be found in the appendix. Except where noted, a five-point Likert scale was used for each measure, with 1 = strongly disagree to 5 = strongly agree.

Objectivity. Objectivity of the A3 Report is defined as approaching and solving a problem using the A3 Report based on field data, and not guided by the personal opinions of participating individuals. We developed a three-item scale to measure the objectivity of the A3 Report, guided by the extant literature (Carlile, 2002) and our field experience (Cronbach alpha = 0.66).

Knowledge integrability. Knowledge integrability of the A3 Report is defined as its ability to stimulate concerns and identify dependencies among the organizational members to develop a shared understanding of how the new process should work to meet the organizational goals. We used a six-item scale to measure knowledge integration. The Likert scale was developed based on the review of the literature and our field experience (Cronbach alpha = 0.89).

Communicability. Communicability of the A3 Report is defined as the degree to which it facilitates interactive discussions among the organizational members to resolve a problem. We developed a three-item scale to measure the communicability of the A3 Report, guided by the extant literature (Carlile, 2002; Henderson, 1991, 1995 in particular) and our field experience (Cronbach alpha = 0.59).

Creativity. Creativity of the A3 Report is defined as its ability to invoke innovative ideas from individuals during construction of the current state and the target state diagrams. We developed a five-item scale to measure creativity of the A3 Report, guided by the extant literature (Henderson, 1991). The Cronbach alpha was 0.70.

Simplicity. We defined simplicity of the A3 Report as ease of interpretability and usability by all individuals, irrespective of their educational levels. We developed a three-item scale to measure simplicity based on our field understanding. The response for the second item was coded using a 5-point scale (0-2 hours = 1, 9-10 hours = 5) during analysis. The Cronbach alpha was 0.75.

Control Variable

Following the A3 Process equates to executing certain key steps in the problem solving process that are critical to effective problem solving (such as observing the actual process and experimenting). This was done to investigate the potential effect this factor may have on the relationship between the predictor and criterion variables in process improvement. We used four

Likert-scale items using to measure the A3 process as a control variable anchored at 1 = strongly disagree to 5 = strongly agree (Cronbach alpha = 0.70).

Analysis Approach

As our intent was to identify what characteristics of the A3 Report predicted its effectiveness, we used multiple regression analysis. First we checked for any missing data in the responses, and found none. However, seven respondents had not implemented the new process, or the new process implementation was in progress when the survey was conducted. As a result, they lacked any results on process improvement. Those cases were deleted from the dataset. We checked for outliers in the criterion variable (number of A3 Reports written). Two instances were found to be three standard deviations away from the sample mean, and were deleted from further analysis. As the predictor variables were on the Likert scale, no outliers were observed. In total, nine cases were excluded from the dataset, resulting in 47 data points for subsequent analysis. We then averaged all the items – positively worded and reversed negatively worded questions together – as a measure for each predictor variable.

For each of the two criterion variables, we performed multiple regression analysis to test the hypotheses. Before conducting the regression analysis, we checked the normality assumptions of each predictor variable by drawing the normal probability plot. We applied a square root transformation to the number of A3 Reports criterion variable, and a natural log transformation for two predictor variables (objectivity and knowledge integrability) and the control variable, to induce more normality in the data. We redrew the plots again to ensure normality. The rest of the variables were approximately normal. Prior to conducting the regression analysis, we checked the linearity of each predictor variable with respect to the criterion variables by drawing bivariate scatter plots of the predictor variables versus the criterion variables (transformations included). The plots were approximately linear. Using SPSS software, we constructed four multiple linear regression models. After creating each model, we checked for homoscedasticity of the residuals.

RESULTS

Table 1 presents the means, standard deviations, and the bivariate correlations for the predictor, criterion, and control variables. All correlations between predictor variables are well below 0.75, the level generally accepted as problematic (Masson and Perreault, 1991; Pelled, Eisenhardt, & Xin, 1999). As a cross check, we also computed the variance inflation factor (VIF) scores to check multicollinearity. All scores were well below the standard benchmark score of 10 (Cohen, Cohen, & West, 2003). As evidenced from Table 1, all predictor variables (except creativity) and the control variable are positively correlated with the criterion variables, A3 Report usage and process improvement. In particular, objectivity is significantly correlated ($r = 0.40$, $p < 0.01$) with A3 Report usage. Similarly, knowledge integrability ($r = 0.42$, $p < 0.01$) and communicability ($r = 0.45$, $p < 0.01$) are significantly correlated with process improvement. Simplicity and the A3 Process (control variable) are also somewhat correlated ($r = 0.25$, $p < 0.10$) with process improvement.

Insert Table 1 about here

As we were interested in finding whether the perception of the individuals in the clinical and non-clinical departments (fiscal, administration, and ancillary departments were combined) differed with respect to the three main characteristics that attributed to the effectiveness of the A3 Report, we conducted Two-Sample t-tests for each predictor variable. The results imply no difference in the means, which indicates that the individuals in the clinical and non-clinical departments perceived the different characteristics of the A3 Report in similar ways.

Table 2 presents the results of the multiple regression analysis. Model 1 is the regression of the predictor variables (excluding communicability) against the criterion variable, A3 Report usage. The control variable is not included in the regression because its effects are only realized during problem solving and not during the decision process of whether or not to use the A3 Report. The results indicate that objectivity of the A3 Report is a very strong predictor of its usage ($p < 0.01$), thus supporting **H1a** that objectivity of the A3 Report is positively associated with its repeat usage. The overall model is significant (F-value = 2.31, $p < 0.1$) and explains 18 percent of the variance (R-squared value) in the criterion variable. The other predictor variables do not show a statistically significant relationship with the criterion variable ($p > 0.1$). The plot of residuals against the predicted values shows no pattern.

Insert Table 2 about here

Model 2 is the regression of the predictor variables (excluding knowledge integrability) against A3 Report usage. Objectivity is again a strong predictor ($p < 0.05$), thus supporting hypothesis **H1a**. As can be seen, the model is significant (F-value = 2.25, $p < 0.10$) and explains 18 percent (R-squared value) of the variance in the criterion variable at $p < 0.10$. The other predictor variables do not reliably predict the criterion variable ($p > 0.1$). The plot of residuals against the predicted values is unstructured.

Model 3 is the regression of the predictor variables (excluding communicability) against the criterion variable, process improvement. The model suggests that statistically, knowledge integrability is a moderate predictor of process improvement ($p < 0.10$), thus supporting **H2b**. The other predictor variables fail to predict the criterion variable ($p > 0.1$). The overall model is significant (F-value = 2.06, $p < 0.10$) and explains 20 percent of the variance (R-squared value) in the criterion variable. The plot of residuals against the predicted values shows slight deviation from a structureless pattern.

Model 4 is the regression of the predictor variables (excluding knowledge integrability) on process improvement. As can be seen from the data, communicability is a strong predictor of process improvement ($p < 0.05$), thus supporting hypothesis **H2c**. The remaining predictor variables fail to predict the criterion variable statistically. The overall model is significant (F-value = 2.22, $p < 0.1$) and explains 21 percent of the variance in the criterion variable. The plot of residuals against the predicted values appears randomly scattered.

DISCUSSION

The purpose of this field-based study was to identify the characteristics that predict the effectiveness of the A3 Report as a BO in process improvement. We measured its effectiveness in terms of two dimensions – its repeat usage and improved results as a result of process improvement. The results provide significant support for the hypotheses **H1a**. The finding implies that organizational members perceive the objectivity of the A3 Report as a strong factor in their decision to use it again. Indeed, individuals from both clinical and non-clinical departments perceive the A3 Report to be an objective tool in cross-departmental problem solving. It is a data driven tool and the iconic representation of the current state on the A3

Report mirrors the actual state of current affairs. Thus, there is little apprehension in the minds of the problem solvers about the real problems and their impact on the system. This finding is in agreement with the existing research literature on BO in other problem solving contexts. For instance, Carlile (2002) finds in his research that only when the updated assembly drawing reflected the concerns of all stakeholders (manufacturing engineering and design), did it become an effective BO for negotiation in new product development.

The finding that the A3 Report seems to promote knowledge integrability to improve process outcome supports hypothesis **H2b**. The result implies that organizational members perceive that the A3 Report facilitates knowledge integration among the organizational members during process improvement. This finding seems to be consistent with the findings of other scholars (Bechky, 2003; Carlile, 2002) who find similar results of knowledge integration using other BOs (assembly drawing, prototypes) in new product development contexts.

Our results also offer evidence that communicability is an important characteristic of an A3 Report during process improvement, thus statistically supporting hypothesis **H2c**. In fact, the iconic representation of the current state on the A3 Report stimulates conversation among the organizational members about the difficulties associated with the current state, which in turn leads to development of the target state for better process outcomes. This finding seems congruent with the findings of other researchers who indicate that effective BOs facilitate communication and knowledge interchange in cross-departmental problem solving (Carlile 2002; Henderson 1991, 1998).

Contrary to our arguments, the effect of creativity on repeat A3 Report usage and on process improvement is not statistically supported. One possible explanation for this result is that creativity is statistically related to objectivity ($r = 0.42$, $p < 0.01$), knowledge integrability (r

= 0.50, $p < 0.01$), and communicability ($r = 0.50$, $p < 0.01$), which suggests that the effect of creativity is confounded in the other three predictor variables, resulting in a situation of statistical suppression of its actual predictive power. A second explanation may be that creativity is analogous to a "double-edged sword." It is important that individuals generate new insights to solve problems. The downside is that unless those insights are integrated into a new collective knowledge, they have little impact on process improvement. Thus, it appears that creativity and knowledge integrability may be inexorably intertwined during the problem solving process.

Contrary to our expectations, we find little statistical support that simplicity of the A3 Report is positively associated with its repeat usage or in process improvement. There may be multiple explanations for this limited support. From our informal talks with the individuals in the facility, we discovered that the A3 Report overtly appears to intimidate people by its appearance, but as one dives into it and uses it s/he finds it simple. One individual nicely summed up the above argument; "The A3 [report] … is complicated at first and I can see people not wanting to use it because it is intimidating. I was confused when I actually sat down to put it on paper. It seems so easy when someone tells you how to do it and how it works." Another possible reason for its apparent complication is that it often involves expending some time and effort beyond the daily work schedule to engage in any substantive problem solving.

We included the A3 Process as a control variable in our regression analysis. This variable individually showed significant relationship (F-value = 3.00, $p < 0.10$) when regressed against the criterion variable, process improvement. But, when it was considered with other predictor variables, the pattern of the regression results did not change. However, it slightly weakened the significance level of some of the predictor variables due to its correlation with them.

In sum, four out of ten sub-hypotheses were found to be significant. However, taken together, three out of the five hypothesized characteristics of the A3 Report emerge to predict its effectiveness as a BO. First, the results imply that the organizational members find objectivity of the A3 Report to be a strong determinant for its repeat usage in process improvement efforts. Second, knowledge integrability and communicability seem to be the determinant characteristics of process improvement.

Although the primary thrust in this research study was to investigate the additive effects of the main predictor variables on the criterion variables, we also investigated the joint effects of the predictor variables, or the two-way interactions, on the criterion variable over and above the individual additive effects. We found the two-way interactions by the cross product of two predictor variables. Since we had four main predictor variables in each model, we examined the effect of six two-way interactions. We regressed the four main predictor variables, six two-way interaction variables, and the control variable over the criterion variable using the centered predictor approach suggested by Cohen et al. (2003) for regression analysis containing interactions. The overall model is insignificant ($F = 0.98$, $p > 0.1$) and the R^2 value is 0.24. The four main predictors, as well as the six interaction variables, are statistically insignificant.

Even though our study presents some interesting results, it is not without limitations, and therefore, suggests some areas for follow-up research. First, it is important to note that the results reflect the findings in one organization – specifically, a mid-sized hospital. Since specific characteristics of the site could influence the findings, it is difficult to generalize them. Therefore, results of this study should be interpreted with care. A second limitation is the small number of respondents. A larger respondent size would give more statistical power to the results. A third limitation of this study is that the design is cross-sectional. Therefore, causal relationships cannot be established among the study variables. Finally, the fourth limitation is the threat of common method variance because all variables or constructs were measured using the same survey instrument.

Future empirical research should extend this work by focusing on the use of the A3 Report in multiple organizational settings (manufacturing and non-manufacturing) to validate the characteristics of a BO discussed in this paper in order to generalize the results. Furthermore, such studies should be replicated at multiple points in time. We hope future research will also attempt to address any other relevant characteristics of a BO not addressed in our research that would enhance the understanding of the A3 Report as a potential BO in cross-departmental problem solving.

CONCLUSION

Despite these limitations, the results have potentially important implications for the academic literature and real world practice. Most studies have examined the role of BOs in different problem-solving contexts qualitatively. Furthermore, most of the attention has been focused on new product development and very little on process improvement. We argue that process improvement is critical to remain competitive and viable in today's dynamic environment. From that perspective, we have addressed a significant gap in empirical research on BOs. We examined the A3 Report's characteristics as a BO in process improvement using a field-based survey, and in the process we validated and strengthened the findings of prior work.

From the viewpoint of real world practice, the findings are also noteworthy. Even though the research is focused in one organizational setting in healthcare, the challenge of integrating knowledge across functional departments is not just limited to healthcare but seems to apply to all organizations, as found by numerous scholars (Brown & Duguid, 1998; Carlile 2002; Soo et al., 2002). From the analysis, the A3 Report appears to be an objective tool that promotes communication and integrates the specialized knowledge of individuals from different functional departments to work toward a common purpose in improving organizational work processes. Finally, we conclude with the fervent hope that the A3 Report has the potential to emerge as an effective BO in many other work settings that need process improvement.

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APPENDIX

Variables	Measures	Alpha
Process Improvement	1. I observed positive results within a few weeks of implementing the target state 2. The change in performance after implementation of the A3 Report: a) Staff productivity b) Wasted time c) No. of errors d) Labor costs e) Material costs f) Patient care	0.87
Objectivity	1. The steps followed in the A3 Report are dependent on personal opinion 2. The steps followed in the A3 Report are based on unbiased data 3. Different individuals with different background will reach similar conclusions by using the steps of the A3 Report	0.66
Knowledge Integrability	1. The A3 Report rarely helped me share problems, mistakes, or concerns about current work processes with other functional departments and reconcile our differences 2. By drawing the current state on the A3 Report everyone had a better understanding of the work processes that spans across many departments 3. A3 Report helped me and others participating in the project to visualize the problem in all its dimensions 4. By using the A3 Report, we developed solutions that involved how the work processes of various departments would be linked together to achieve organizational goals 5. By writing the A3 Report I have a deeper understanding of the work processes and why we do it that way 6. By being involved in the A3 Report, I became more knowledgeable of the work processes of other departments as well	0.89
Communicability	1. A3 Report facilitates quick and easy communication with others 2. The pictures (current state and target state) encouraged communication among different members of the A3 team 3. A3 Report became a common ground for conversation among different members of the A3 team	0.59
Creativity	1. By using pencil and paper in writing the A3 Report, I was involved in free exploration of ideas 2. I drew and redrew sketches of the current state multiple times with a pencil to ensure that my mental imagination truly represented the actual current state 3. While drawing the target state with a pencil I was involved in creative and conceptual thinking about how	0.70

	to improve existing work processes 4. Writing A3 Reports by hand encouraged me to be aware of the bigger picture 5. The A3 Report written by pencil can be easily passed around to other participants to draw out ideas	
Simplicity	1. Writing the A3 Report requires a high level of skill and education 2. It took me ___ hours to write the A3 Report 3. We spent a lot of money to effect the change as suggested in my A3	0.75
A3 Process	1. Observing current state was important for my study 2. I designed the target state based on three design (specifying activities, creating direct connection, and simplifying pathways) rules of TPS 3. I carried out a test for my A3 Report 4. I and others have been able to verify our understanding of the improved process by devising a test and comparing the actual results with the predicted results	0.70

TABLE 1

Means, Standard Deviations, and Correlations among Study Variables

	1	2	3	4	5	6	7	8
1. A3 Report[a]								
2. Process Improvement	0.29*							
3. Objectivity[b]	0.40**	0.23						
4. Knowledge Integrability[b]	0.13	0.42**	0.30*					
5. Communicability	0.19	0.45**	0.51**	0.76**				
6. Creativity	0.05	0.22	0.42**	0.50**	0.50**			
7. Simplicity	0.16	0.25†	0.33*	0.37*	0.37*	0.16		
8. A3 Process[b]	0.31*	0.25†	0.21	0.40**	0.48**	0.25†	0.13	
Mean	1.18	2.90	1.41	1.49	4.21	4.46	4.19	1.39
Standard Deviation	0.64	0.33	0.19	0.14	0.82	0.5	0.65	0.20

Notes: N = 47
[a] Square root transformed
[b] Natural log transformed
† $p < 0.10$
* $p < 0.05$
** $p < 0.01$

TABLE 2

Results of Regression Analysis[a]

Variables	Model 1 (A3 Report Usage)	Model 2 (A3 Report Usage)	Model 3 (Process Improvement)	Model 4 (Process Improvement)
A3 Process			0.15	0.08
Objectivity	1.43**	1.41*	0.15	-0.03
Knowledge Integrability	0.39		0.80†	
Communicability		0.03		0.16*
Creativity	-0.22	-0.19	-0.02	0.00
Simplicity	0.01	0.03	0.05	0.05
R-squared	0.18	0.18	0.20	0.21
Adj. R-squared	0.10	0.10	0.10	0.12
F-value	2.31†	2.25†	2.06†	2.22†

[a] N = 47
† $p<0.10$
* $p<0.05$
** $p<0.01$

FIGURE 1

A3 Report Template

THEME: "What are we trying to do?"

To:___________________
By: ___________________
Date:___________________

Background

- Background of the problem
- Importance of the problem; how it impacts company's goals or values

Current Condition

- Diagram of how the current process works.
- Key problem(s) noted
- Quantified measures of the extent of the problem(s)

Cause Analysis

- Key problem(s), and most likely root cause(s)

Why?
Why?
Why?
Why?
Why?

Target Condition

- Diagram of how proposed process will work
- Specific countermeasures noted
- Measurable targets (quantity, time)

Implementation Plan

What?	*Who?*	*When?*	*Where?*
Actions to be taken	Responsible person	Times, Dates	

Cost:

Follow-Up

Plan	*Actual Results*
• How will you check the effects? • When will you check them?	• In red ink/pencil. • Date check done. • Results, compare to predicted.