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# A Socio-technical Process Model for Improving the Requirements Analysis Phase of Socio-technical System

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# A SOCIO-TECHNICAL PROCESS MODEL FOR IMPROVING THE REQUIREMENTS ANALYSIS PHASE OF SOCIO-TECHNICAL SYSTEM

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We certify that we have read this dissertation and that, in our opinion, it is satisfactory in scope and quality as a project for the degree of Doctor of Science in Information Systems.

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# ABSTRACT

Software development is the process of building systems that solve users' need and satisfy stakeholders objectives. Such needs are determined through a requirements elicitation process, which is considered an intensive, complex, and difficult by its nature, and the multi-disciplinary nature of it adds to this complexity. As a result, improving the elicitation process is a critical goal for the development of information systems since incomplete requirements is a primary cause of system development failure.

Traditional methods of elicitations failed because these methods focus only on the technical aspects and constraints of the systems. The success of information system development involves the identification of the social, organizational and technical features of the systems, which in turn results in a more acceptable system by users. As a result, socio-technical systems design methods have been widely discussed in literature, and aim at giving equal weight to the social and technical issues during system design.

This research aims to address a number of problems through the development and evaluation of a Socio-Technical (ST) process model that aims to provides a systematic process for requirement elicitation of ST systems, accounts for social and technical aspects of systems, improve requirement elicitation questionnaire quality, and improve analysts' domain knowledge and interview readiness.

In this dissertation, we explore the potential for a socio-technical process model in enhancing analysts' domain knowledge for the requirements elicitation phase. More specifically, we explore the potential for the socio-technical process model to enhance analysts' domain knowledge, interview readiness, and the questionnaire quality that they will use to gather the necessary system requirements. Following design science guidelines, we have developed a socio-technical process model with demonstration in the self-care management area. Evaluation is done using empirical investigation with a randomized two group experimental design, where the objective is to see the potential for the proposed process model in enhancing analysts' domain knowledge, interview readiness, and questionnaire quality.

# DECLARATION

I hereby certify that this dissertation constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions or writings of another.

I declare that the dissertation describes original work that has not previously been presented for the award of any other degree of any institution.

Signed,

Abdullah Wahbeh

Abdullah Hamdi Saleh Wahbeh

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# CHAPTER 1

# INTRODUCTION

## Background of the Problem

Software development is the process of building systems that solve users' need and satisfy stakeholders objectives (Hickey and Davis 2004). System development consists of many different phases, one of the most important phases is the requirements analysis phase. Requirements analysis is the phase during which system users' needs are determined.

Such needs are determined through a requirements elicitation process (Raghavan, Zelesnik et al. 1994, Toro, Jiménez et al. 1999), which is considered an intensive, complex, and difficult by its nature (Brooks 1987, Hickey and Davis 2003), and the multi-disciplinary nature of it adds to this complexity (Zowghi and Coulin 2005). As a result, improving the elicitation process is a critical goal for the development of information systems since incomplete requirements is a primary cause of system development failure (Davis 1982, Byrd, Cossick et al. 1992, Pitts and Browne 2007). In essence, successful collection of users' requirements is crucial for the success of information system development (Browne and Rogich 2001).

In addition, many systems design problems today are new, complex and difficult. They are outside the system designers' normal experience and there may be few experts available to give advice. Also the consequences of not tackling them successfully may be a serious disaster (Mumford 2000). Most of the design problems are also related to directly to requirements elicitation.

Traditional methods of elicitations failed because these methods focus only on the technical aspects and constraints of the systems. The success of information system development involves the identification of the social, organizational and technical features of the systems (Clegg 2000), which in turn results in a more acceptable systems by users. As a result, socio-technical systems design methods have been widely discussed in literature (Mumford 2000, Berg and Toussaint 2003, Eason 2007, Baxter and Sommerville 2011), and aim at giving equal weight to the social and technical issues during system design (Mumford 2000). Baxter and Sommerville (2011) refer to sociotechnical systems design (STSD) methods as "an approach to design that considers human, social and organizational factors, as well as technical factors in the design of organizational systems".

In the context of requirements elicitation, interviews is the major technique for getting the requirements from the actors in the organization (Davis 1982, Agarwal and Tanniru 1990, Sampaio do Prado Leite and Gilvaz 1996, Pitts and Browne 2007, Baloian, Zurita et al. 2011, Vitharana, Jain et al. 2012). Interviews, whether they are structured, semi-structured, or un-structured, are considered one of the most effective requirements elicitation techniques. The interview process consists of many phases, including creation of questions, identifying and selecting interviewee, planning the interview process, conducting interview, and close the interview meeting (Vasundran 2012). Without proper attention to these tasks, the system analysts are likely to 'short-cut' the requirements elicitation process, which in turn affects the completeness and accuracy of the elicited requirements (Pitts and Browne 2007).

In interviews, the system analysts collect the necessary requirements with a set of questions to gain necessary information about their needs (Lim and Finkelstein 2012). However, there is a limited guidance about the interviews contents or questions (Moody, Blanton et al. 1998, Browne and Rogich 2001), and the kind of questions or inquiry that is most effective (Pitts and Browne 2007). Finally, when it comes to experience, empirical studies show that the "careful preparation of interviews may have a much more marked effect than experience" (Davis, Dieste et al. 2006). In other words, "a novice analyst who prepares the interview well beforehand is even capable of eliciting more information than an experienced analyst" (Davis, Dieste et al. 2006).

## Statements of the problem

Interviews are exploratory in nature and tend to be less guided, and characterized by a set of questions, such as "what the system should do", where the depth and breadth of each of these questions is largely dependent on the analysts skills and experience (Hubbard, Schroeder et al. 2000), where those analysts usually do not employ any structured or rigorous processes to address requirements elicitations.

In some cases, interviews may consists of unnecessary questions that can lead to eliciting the wrong requirements (Kato, Komiya et al. 2001). Empirical studies showed that careful preparation of interviews has a much more marked effect than analyst experience (Davis, Dieste et al. 2006).

In some cases, novice analysts are capable of eliciting the necessary requirements exactly the same way as experienced analysts. In fact, careful preparation of interviews has a much more marked effect than analyst experience (Davis, Dieste et al. 2006).

Analyst "*from traditional software engineering backgrounds may sometimes focus on the solution not the problem, and reply on only those techniques they are familiar with for all situations*" (Aurum and Wohlin 2005, Zowghi and Coulin 2005). In some cases, it is necessary to investigate and examine the application domain in which the system will reside (Zowghi and Coulin 2005). Such investigation should not be limited to technical aspects of the problem domain but should also include the political, organizational, and social aspects related to the system (Aurum and Wohlin 2005, Zowghi and Coulin 2005)

In the Socio-Technical System literature, there is a lack of a midrange theoretical model for STS analysis and design. The studies we have, (Cherns 1976, Cherns 1987, Clegg 2000, Mumford 2006, Lyytinen and Newman 2008, Baxter and Sommerville 2011), are very abstract and do not provide any artifact, specific steps, or process for the purpose of practicing STS analysis and design.

**Research Objectives**

This research aims to address the aforementioned problems through the development and evaluation of a Socio-Technical (ST) process model that aims to:

- Provides a systematic process for requirement elicitation of ST systems.
- Accounts for social and technical aspects of systems
- Improve requirement elicitation questionnaire quality
- Improve analysts' domain knowledge and interview readiness

# CHAPTER 2

# LITERATURE REVIEW

## Requirements Elicitation - Interviews and Domain Knowledge

System development is the process of creating software systems that are used to solve important users' problems, satisfies users' needs and leverages their opportunities, or satisfies their needs (Hickey and Davis 2004). System development is done using one of the well-known system development methodologies that are based on the concept of system development life cycle (SDLC), such methodologies include the Waterfall system development methodology (Boehm 1988), rapid application development (RAD) (Martin 1991), and agile software development (Beck, Beedle et al. 2001).

Each system development methodology consists of a number of phases, where these phases can be divided into sub-phases. Each phase or sub-phase consist of a number of activities that need to be done in order to finalize a phase and deliver some artifacts.

Requirements engineering is the branch of software engineering that is concerned with objectives, functionalities and constraints associated with any software system (Lee and Zhao 2006). In requirements engineering, one of the most important activities that is part of any system development methodology is called requirements elicitation, sometimes referred to as requirements gathering or requirements collection. It is considered one of the first steps in the software life cycle, its importance is becoming more and more prominent (Liu and Lin 2008) as it helps analysts and those involved in system development to learn and discover users and stakeholders' needs (Kenzi, Soffer et al. 2010).

Requirements elicitation is one of the most critical steps in software development where poor execution of the elicitation process can results in a complete failure of the project (Hofmann and Lehner 2001, Hickey and Davis 2004). As a result, there is a need to improve the process of requirements elicitation and avoid such dramatic impact that results from the poor execution of such important process.

In literature, there are different requirements elicitation techniques that can help analysts to identify and elect users and stakeholders' needs. These techniques include but not limited to interviews, ethnography, prototyping, data gathering from existing systems, formal methods, card sorting, brainstorming, requirements workshop, JAD, scenarios , and viewpoints (Zowghi and Coulin 2005, Sabahat, Iqbal et al. 2010).

Analysts are not limited to one specific requirements elicitation techniques and they can use different techniques together depending on the situation and the problem domain (Kenzi, Soffer et al. 2010, Hadar, Soffer et al. 2014). One of the most popular and widely used methods for eliciting the necessary requirements is interviews (Davis, Dieste et al. 2006, Kenzi, Soffer et al. 2010, Sutcliffe and Sawyer 2013, Hadar, Soffer et al. 2014). Interviews are considered effective techniques for collecting requirements using structured, semi-structured, or unstructured questions depending of the situation. In an extensive literature review, none of the available requirements elicitation methods was found to have advantages over semi-structured interviews (Davis, Dieste et al. 2006, Sutcliffe and Sawyer 2013) or structured interviews (Hickey and Davis 2004, Sutcliffe and Sawyer 2013). Interviews have been rated as being the most effective technique used by analysts for gathering the necessary requirements (Chua, Bernardo et al. 2010).

As mentioned earlier, requirements elicitation is all about determining users and stakeholders' need (Hickey and Davis 2004), where the process itself involves examining and reviewing existing systems, any relevant documents, interviewing relevant users and stakeholders' (Vitharana, Jain et al. 2012). This means that the requirements elicitation process consists of many knowledge-intensive processes (Hickey and Davis 2003). As a result, accessing such knowledge is considered crucial to the success of the requirements elicitation process, which in turn can result in a more acceptable and successful systems.

In this context, it seems that obtaining such knowledge before proceeding with the requirements elicitation task is beneficial for an analyst (Kenzi, Soffer et al. 2010). "Knowledge of the business domain such as insurance claim and human resources is crucial to analysts' ability to conduct good requirements analysis" (Vitharana, Jain et al. 2012). In literature, a number of studies have addressed the role of domain knowledge in requirements elicitation task as shown in table 1.

Table 1. Domain knowledge in requirements elicitation

| Article | Research Question/Objectives | Methodology/Approach | Evaluation |
|---|---|---|---|
| Omoronyia, Sindre et al. (2010) | Building a domain ontology that is sufficient for guided requirements elicitation | The use of rule-based approach for building the domain ontologies from natural language technical documents | Evaluation of the proposed approach was based on a real-world industrial use case by analyzing natural language text from technical standards |
| Vitharana, Jain et al. (2012) | Design a knowledge based component repository (KBCR) for facilitating requirements analysis | Authors used prototyping and illustrated its application in a system that is populated with components and process templates for the auto insurance claim domain | Empirical investigation using assessment model, hypothesis development, variable measurement, experimental design and data collection, and data analysis |
| Nakamura, Takura et al. (1994) | Proposed a method for generating specifications from partial information capable of supplying missing information, using the domain model. | Building a requirements elicitation system based on domain model, where the domain model itself is held as a knowledge base. | The use of a number of theoretical test cases. |
| Liu and Lin (2008) | A theoretical automated requirement elicitation approach | Based on machine learning techniques in decision making this paper proposed a | Implementing an automated requirements elicitation tool and |

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|---|---|---|---|
| | based on decision making under complete knowledge assumption. | requirements model selection process based on a comparatively complete domain knowledge base, the requirements are represented as goal models. | a basic experimental platform which implements the requirements decision making process, the basic algorithm and function, and the four evaluation functions including random selection. |
| Ugai and Aoyama (2009) | Designed a wiki system to accumulate domain knowledge that can help understanding users' requirements. | The use of pattern language to transfer domain knowledge. | NA |
| Kaiya, Shimizu et al. (2010) | A method and a tool to enhance an ontology of domain knowledge for eliciting requirements using Web mining | An ontology enhancement method that divide an ontology into sub-domain ontologies, gather web pages, mine candidates of new concepts and prioritize them, and choose new concepts to be added | Test a set of hypothesis using a comparative experiment approach |
| Mohd Kasirun and Salim (2008) | A model for requirements elicitation using focus group discussion technique | A focus group discussion for requirements elicitation (FGDRE) gives an understanding about the requirements elicitation activity | NA |

| | | | |
|---|---|---|---|
| | | and recommends essential requirements for requirements elicitation tool. | |
| Shibaoka, Kaiya et al. (2007) | GOORE (Goal-Oriented and Ontology Driven Requirements Elicitation) method | A goal oriented modeling method which was combined with an ontological technique to utilize domain knowledge. | A small experimental case study to investigate the usefulness of the proposed approach. |
| Dzung and Ohnishi (2009) | Develop an a requirements ontology for eliciting requirements of a certain problem domain | Using the ontology, authors established a method of checking the quality of a Software Requirements Specification (SRS), especially the correctness and the completeness. | To illustrate the proposed method, authors used a library system as an example. |
| Dzung and Ohnishi (2009) | An ontology based reasoning method for eliciting requirements as well as, a framework to elicit requirements using ontology | Use an ontology structure that contains knowledge of functional requirements and relations among them. Map initial requirements to functions in domain ontology. Then use rules and relations among functions to reason for errors and potential requirements | Future work: assign two groups of analysts to working on the same requirements elicitation problem and conduct an experiments to compare the results of the requirements elicitation work using the proposed ontology-based checking tool and the |

| | | | |
|---|---|---|---|
| | | | requirements elicitation work without using it. |
| Xiang, Liu et al. (2007) | Proposed an automated Service Requirements Elicitation Mechanism (SREM) to help extract and accumulate relevant knowledge on service requirements. | A service requirements and capability ontology is adopted to capture services requirements in breadth and precision. | Applied the proposed approach on a simple web process of order-processing. |
| Kenzi, Soffer et al. (2010) | The effect of domain knowledge on the elicitation process. | Qualitative and quantitative methods. | Interviews, questionnaires, and qualitative analysis. |
| Zong-yong, Zhi-xue et al. (2007) | A multiple ontology framework for requirements elicitation and reuse. | A framework that consists of top level ontology, domain ontology, task ontology, application ontology, ontology based requirements elicitation, and ontology based requirements reuse. | NA. |
| Kaiya and Saeki (2006) | A requirements elicitation method based on ontology, where a domain ontology can be used as domain knowledge. | Using inference rules on the ontology and a quality metrics on the semantic function, an analyst can which requirements should be added for improving completeness of the current requirements and/or which | Experimental case study of software music players. |

| | | | |
|---|---|---|---|
| | | requirements should be deleted from the current version for keeping consistency. | |
| Demirors, Gencel et al. (2003) | A new approach for eliciting requirements based on business processes. | Process implementation that consists of management and technical implementation and quality assurance implementation. | NA |

According to Vitharana, Jain et al. (2012), analysts’ knowledge of the domain is particularly crucial in their interactions with users. When analysts used to work in the same domain on different projects, the knowledge gained in previous projects can help determine the necessary requirements more effectively for the current project (Kaiya, Shimizu et al. 2010, Hadar, Soffer et al. 2014). Such knowledge can be obtained in different ways. One of the most popular and widely used method is using what we call ontologies. “Ontologies are used to reconcile gaps in the knowledge and common understanding among stakeholders” (Omoronyia, Sindre et al. 2010).

Sometimes analysts have the necessary experience in systems development, on the other, the knowledge they have about the problem domain is usually limited (Vitharana, Jain et al. 2012). A study found that “28% of the job openings for of Fortune 500 firms required applicant analysts to have knowledge of a specific industry” (Lee 2005, Vitharana, Jain et al. 2012). Moreover, a “lack of domain knowledge leads analysts to rely primarily on users for learning about the domain” (Coughlan and Macredie 2002, Vitharana, Jain et al. 2012). By doing so, they put additional burden on the users as well as they can form a biased view of the domain. So, it is important to know about the business domain as well as understand the domain problem by obtaining the necessary knowledge that can help better understand users’ need, which in turns helps in eliciting the necessary requirements more efficiently and effectively.

**Socio-Technical Systems**

The idea and notions of Socio-Technical systems and Socio-Technical design started more than 50 years ago (Mumford 2006). Since its establishment back in 1946, The Tavistock Institute for Human Relations, located in London, is widely credited with the continuous development of the concepts and practices related to Socio-Technical systems design (Scacchi 2004, Mumford 2006). The term Socio-Technical systems was originally coined by Emery and Trist (1960) to describe the behavior of many systems that already exists and involves complex and sophisticated interaction among a number of elements including humans, machines, and the surrounding environment. Nowadays, for most of existing system, such kind of complex sophisticated interactions is true (Baxter and Sommerville 2011).

The term Socio-Technical systems is made up of two core concepts, namely social system and technical system, and is viewed as the sum of and interplay of these social and technical systems (Cummings 1974, Cooper, Gencturk et al. 1996, Lee and Xia 2005, Hanssen 2012). The technical system covers the technology and its associated work structure, where the social system covers the individual and their grouping in teams as well as the coordination, control and boundary management (Mumford 2006). The term Socio-Technical systems "includes the network of users, developers, information technology at hand, and the environments in which the system will be used and supported" (Scacchi 2004).

According to Baxter and Sommerville (2011), Socio-Technical systems design (STSD) methods "are an approach to design that consider human, social and organizational factors, as well as technical factors in the design of organizational systems". In this context, organizational refers to company or business related factors while social refers to factors related to the relationships between people who interact together within and across organizations (Baxter and Sommerville 2011, El-Gayar, Sarnikar et al. 2013).

The ultimate objective of Socio-Technical systems design is the 'the joint optimization of the social and technical systems' (Mumford 2006). Also, social and technical aspects of the system should be given equal weight when we consider the development of new systems, since these factors will influence the functionality and usage of any computer-based systems (Appelbaum 1997, Mumford 2006, Baxter and Sommerville 2011, Trist, Higgin et al. 2013).

In particular, "in a Socio-Technical system, human, organizational and software actors rely heavily on each other in order to fulfill their respective objectives" (Bryl, Giorgini et al. 2009). Unlike traditional information systems that considers the software pieces, or the technical side of the system, Socio-Technical system include also the organizational and human actors in the architecture and operation of these traditional systems along with the technical piece, "and are normally regulated and constrained by internal organizational rules, business processes, external laws and regulations" (Sommerville 2004, Bryl, Giorgini et al. 2009, Chopra, Mylopoulos et al. 2010). Towards this objective, Cherns (1976), (1987) identified a number of principles for socio-technical design. Where, Clegg (2000), presents a revised set of these sociotechnical principles to guide system design, and to consider the potential roles and contributions of such principles (El-Gayar, Sarnikar et al. 2013, 2014). The list of Socio-Technical principles are shown in Table 2.

Table 2. Principles for Socio-Technical design

| Authors | Socio-Technical Principles |
|---|---|
| Cherns (1976) | Compatibility, minimal critical specification, the socio-technical criterion, the multi-functionality principle, boundary location, information flow, support congruence, design and human values, and incompletion. |
| Cherns (1987) | Compatibility, minimal critical specification, variance control, boundary location, information flow, power and authority, the multifunctional principle, support congruence, transitional organization, and incompletion or the forth bridge principle. |
| Clegg (2000) | Meta-principles: design is systemic, values and mindsets are central to design, design involves making choices, design should reflect the needs of the business, its users and their managers, design is an extended social process, design is socially shaped, and design is contingent.<br>Content principle: core processes should be integrated, design entails multiple task allocations between and amongst humans and machines, system components should be congruent, systems should be simple and make problems visible, problems should be controlled at source, the means of undertaking tasks should be flexibly specified.<br>Process principle: design practice is itself a sociotechnical system, systems and their design should be owned by their managers and their users, evaluation is an essential aspect of design, design involves multidisciplinary education, resources and support are required for design, system design involves political processes |

The principles are intended to be applied to the design of new systems and they attempt to provide a more integrated perspective than is apparent in existing formulations. Clegg (2000) categories these principles into three types namely Meta, content and process that are highly interrelated. As stated by the author, these principles are to be used by system managers, users, designers, technologists and social scientists. They provide inputs to who are engaged collaboratively in design (El-Gayar, Sarnikar et al. 2013, 2014).

Principle 1. Compatibility: "the process of design must be compatible with its objectives. So, if the objective of design is a system capable of self-modification, of adapting to change, and of making the most use of the creative capacities of the individual, then a constructively participative organization is needed" (Cherns 1976, Cherns 1987).

Principle 2. Minimal critical specification: this has two aspects, negative and positive. The negative states "no more should be specified than is absolutely essential". On the other hand, the positive states that "essential must be specified" (Cherns 1976, Cherns 1987). "While it may be necessary to be quite precise about what has to be done, it is rarely necessary to be precise about how it is to be done" (Cherns 1976, Mumford 2006).

Principle 3. The Socio-Technical criterion / variance control: variances or deviations from expected norms and standards must be eliminated or at least must be controlled as near to their point of origin as possible. "Problems of this kind should be solved by the group that experiences them and not by another group such as a supervisory group" (Cherns 1976, Cherns 1987, Mumford 2006).

Principle 4. The multi-functionality principle: redundancy of functions is a characteristic of work that can help individuals to adapt and learn. "For groups to be flexible and able to respond to change, they need a variety of skills. These will be more than their day-to-day activities require" (Cherns 1976, Cherns 1987, Mumford 2006).

Principle 5. Boundary location: "boundaries should facilitate the sharing of knowledge and experience. They should occur where there is a natural discontinuity - time, technology change, etc. - in the work process. Boundaries occur where work activities pass from one group to another and a new set of activities or skills is required. All groups should learn from each other despite the existence of the boundary" (Cherns 1976, Cherns 1987).

Principle 6. Information flow: "this principle states that information systems should be designed to provide information in the first place to the point where action on the basis of it will be needed" (Cherns 1976, Cherns 1987).

Principle 7. Support congruence: "systems of social support should be designed so as to reinforce the behaviors which the organization structure is designed to elicit" (Cherns 1976, Cherns 1987).

Principle 8. Design and human values: "the objective of organizational design should be to provide a high quality of work" (Cherns 1976, Cherns 1987), "where such quality work requires, jobs to be reasonably demanding; opportunity to learn; an area of decision-making; social support; the opportunity to relate work to social life; and a job that leads to a desirable future" (Cherns 1976, Cherns 1987, Mumford 2006).

Principle 9. Incompletion or Forth Bridge principle: design is an iterative process and never stops. "New demands and conditions in the work environment mean that continual rethinking of structures and objectives is required" (Cherns 1976, Cherns 1987, Mumford 2006).

Principle 10. Power and authority: "Those who need equipment, materials, or other resources to carry out their responsibilities should have access to them and authority to command them. In return, they accept responsibility for them and for their prudent and economical use. They exercise the power and authority needed to accept responsibility for their performance. But there is also the power and authority that accompanies knowledge and expertise" (Cherns 1987).

Principle 11: Transitional organization: "experience since 1976 is responsible for the addition of this principle. As we are engaged in change from a traditional to a new organization, from a traditional to a new philosophy of management, from an old to a new system of values, we need to see the design team and its process as a vehicle of transition" (Cherns 1987).

Clegg (2000) has addressed the same principles and proposed new one along a hierarchy of three kind of principles, namely Meta, content, and process. Clegg (2000) has addressed principle 1 under the principle that state that 'systems and their design should be owned by their managers and users'. Under this principle, Clegg (2000) has emphasized on user ownership instead of focusing on user participation like Cherns's principles. Cherns (1976) and Cherns (1987) focused on the need for compatibility between process and outcome, and this highlighted the need to involve users in design. The emphasis by Clegg (2000) is on the related "notions of ownership and appropriation, that is with who owns the new system and the processes through which it is designed and implemented".

Principle 2 is also addressed by Clegg (2000) where the users should be allowed to solve their own problems and develop their own methods of working, thereby incorporating scope for learning and innovation. Such situation is very difficult to achieve in bureaucratic organizations where standard and common working practices may be the norm.

Principle 3 is addressed in the same way by Clegg (2000) under the principle called ‘problems should be controlled at source’ where variances (called un-programmed events) should be controlled at source. Principle 4 has been extended by Clegg (2000) to incorporate consideration of task allocation between humans and machines. Sociotechnical systems consist of allocating tasks to and between humans and machines (Clegg 2000).

Principles 5 and 6 were addressed by Clegg (2000) under the ‘Core processes should be integrated’ principle by viewing the organization as comprising a number of core processes that typically cut laterally across different functions, not like the traditional, where it is comprise sets of expertise-based specialisms that are organized vertically. Principle 7 has been extended by Clegg (2000) by considering that a new designs involve a set of working arrangements and these needs to be congruent with surrounding systems and practices. These new systems become integrated into existing ones, but such systems may require some accommodation by the systems into which it is being placed (Clegg 2000).

Principle 9 has been addressed by Clegg (2000) the ‘transitional organization and incompletion’ principle, where this principle states that systems that undertake design also need designing, and that sociotechnical thinking, ideas and principles are applicable to such systems.

The remaining principles addressed by Clegg (2000) are either not addressed completely by Cherns’s principles of STS design or addressed implicitly under some of the Cherns’s principles. For example, ‘Design is systemic’ is implicit in Cherns’s principles and arguments. Also, the principle of ‘values and mindsets are central to design is similar to the views presented by Cherns. The principle of ‘design involves making choices’ was briefly considered social options under his principle of minimal critical speciation. In addition, the principle of ‘evaluation is an essential aspect of design’ was mentioned briefly under Cherns’s principle of incompletion. On the other hand, the principles of ‘design involves multidisciplinary education’, ‘design is contingent’, ‘resources and support are required for design’, and ‘system design involves political processes’ were not included in Cherns’s principles, but the notion of these principles were implicit in his ideas. Finally, the principles of ’design should reflect the needs of the business, its users and their managers', 'design is an extended social process', 'design is socially shaped', and 'systems should be simple in design and make problems visible' were not covered by Cherns.

Socio-Technical theory represents an important frontier as an effective design tool for new technology (Cooper, Gencturk et al. 1996), thus provides a basis for analyzing and designing systems so that social and technological systems are jointly optimized (Cooper, Gencturk et al. 1996, Baxter and Sommerville 2011). Aside from the Socio-Technical principles, researchers have always tried to test and develop a Socio-Technical theory (Mumford 2006). The Socio-Technical systems theory was originally developed from open systems theory (Von Bertalanffy 1950).

Many researchers have tried to suggest enhancements to Socio-Technical systems (STS) theory (Majchrzak and Borys 2001). Taylor and Felten (1993) refer to Socio-Technical system design as a philosophy and a methodology. (Gerwin and Kolodny 1992) refers to Socio-Technical system as a "paradigm" consisting of a conceptual scheme, a methodology, a design process, a set of values about work, contextual conditions such as interdependence with the environment, and an historical tradition built on psychology, sociology and workplace research. Emery (1993) refers to Socio-Technical system design as a generalized model of the dimensions of social and technical.

While the aforementioned discussion referred to an organizational context, we hereby argue that socio-technical considerations are also applicable to pervasive and ubiquitous systems for self-care, self-management, and patient empowerment, as well as many other domains. Significant work has been done in various areas of pervasive computing application design including architectures and protocols (Bakhouya 2009), service compositions (Zhou, Gilman et al. 2011) and user interface design (Mei and Easterbrook 2007). Nevertheless, with the exception of Crabtree et al. (2006), most research in pervasive systems design is oriented towards technological aspects and is not people focused. The key challenge in pervasive technology design is to move the focus from pure technology to contexts of daily life (Thackara 2001). According to Tang et al. (2011) "The design of pervasive computing applications has emerged as a notable research area". Understanding user task goals, user interactions and capturing appropriate context are some of the open issues that remain in supporting the design of pervasive computing applications.

Socio-Technical theory has been addressed and applied to the design and development of information systems. The work by Lyytinen and Newman (2008) is considered one of the One of the notable work in this area, where the authors have demonstrated how the Leavitt's model for organizational change can be adapted as a Socio-Technical model for analyzing information systems implementation and change (Leavitt 1964, Kwon and Zmud 1987, Lyytinen and Newman 2008) and apply it to any context or domain. Lyytinen and Newman (2008) have outlined a punctuated socio-technical information system change model that can be used as a device to describe complex information system changes. Those changes are targeted towards deliberating a "change to an organization's technical and organizational subsystems that deal with information" (Swanson 1994, Lyytinen and Newman 2008).

Information system change "re-configures a work system by embedding into it new information technology components" (Alter 2002, Lyytinen and Newman 2008). On the hand, a separate system, called building system, "commands a set of resources and enacts routines to carry out the change and address the issues of uncertainty, ambiguity, and complexity" (Lyytinen, Mathiassen et al. 1996, Lyytinen and Newman 2008). Both systems, work and building, are embedded in broader system called organizational environment (Lyytinen and Newman 2008). Such environment can be divided into two distinct parts, organizational context and environmental context or the inner context and the outer context (Pettigrew 1990, Lyytinen and Newman 2008, Ahmad, Lyytinen et al. 2011).

The nature of information system changes can be described along to paradigms. One paradigm is incremental and continues and the other is episodic and revolutionary. In the incremental and continues "change accrues from a slow stream of small mutations", where in the episodic and revolutionary paradigm compact periods of metamorphic change are followed by periods of stability and slow and small mutations (Lyytinen and Newman 2008, Schellhammer 2010). For the purposes of punctuated socio-technical information system change model, Lyytinen and Newman (2008) stated that similar to information system failure and adaptation studies, information system change is "not solely or even mainly incremental and cumulative, but it primarily, episodic".

In order to characterize the content of any information system change as well as the engine for that change, the Socio-Technical theory has been used by Lyytinen and Newman

(2008), where the Socio-Technical components and their connections are considered the general 'lexicon' for describing the information system change.

In the context of information systems a Socio-Technical system (Figure 1) can be modeled as a collection of four components, namely tasks, actors, structure, and technology and their inter-relationships (Leavitt 1964, Lyytinen and Newman 2008). These four components "build up the technological, the social, the organizational, and the strategic cores of the organization" (Morton 1991, Lyytinen and Newman 2008)

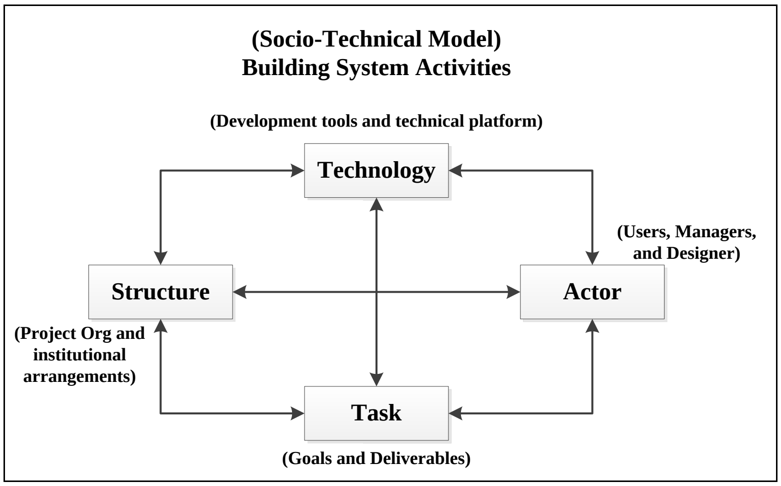


Figure 1. Components of a ST System (Lyytinen and Newman 2008)

Tasks describe the goals and purpose of the system and the way work/activities are accomplished. Actors refer to users and stakeholders who perform and influence the work/activities. Structure denotes the surrounding project and institutional arrangements while technology refers to tools and interventions used to perform the work/activities. Each of the components is identified at the work system level, the building system level, and the organizational environment. Gaps or ST imbalances are identified for the combinations of the components, namely task-actor, task-structure, task-technology, actor-structure, actor-technology, and structure–technology (El-Gayar, Sarnikar et al. 2013, Sarnikar, El-Gayar et al. 2014).

The definition of each S-T component within the S-T model as seen at each system level, and their main properties, the organization theory, and the IS literature can be found in the work by Lyytinen and Newman (2008).

**Requirements Elicitation Issues**

Pillai (2013) studied the challenges and issues related to requirements elicitation using a comprehensive systematic literature review using 4,988 papers extracted from a number of databases, journals, as well as other resources such as books, thesis, and technical reports. Based on the inclusion and exclusion criteria, the authors selected 81 papers for the review. Accordingly, the author identified a number of issues that are related to change, communication, human factors, knowledge, requirements, social and organizational, scope, stakeholder, and tools, technology, and methods (TTM). Analyzing these issues, we can argue that many of them are socio-technical in nature and has a strong connection with the notion of socio-technical systems. For example, the authors has identifies requirements elicitation issues related to skills (Liu, Li et al. 2010, Babar, Ramzan et al. 2011), understanding needs (Hickey and Davis 2003), domain (Liu, Li et al. 2010), knowledge (Kof 2004), process (Pa and Zin 2011, Pacheco and Garcia 2012), complexity (Ashraf and Ahsan 2010), time factor issues (Sabahat, Iqbal et al. 2010) [67], tools (Naz and Khokhar 2009), techniques (Kaiya and Saeki 2006, Liu, Li et al. 2010, Vasundran 2012), and methods (Davis, Dieste et al. 2006, Lee, Kim et al. 2011).

Christel and Kang (1992) have identified several issues related to requirements elicitation where these issues are mainly related to scope, understanding, and volatility. Problems of scope highlight the need for better understating of the system boundaries, where such underrating should include to customers/ end-users and project stakeholders. Problems of understanding related to “poor understanding of what is needed by customers, poor communication on requirements, and lack of knowledge of the available environment in which the system needs to or is currently operating”. Problems of volatility is related to poor management of changing requirements, where unstable requirements can negatively affect any project success. Also, in another study, problems in requirements elicitation can be classified into three main categories, namely, scope, understanding, and volatility (Ashraf and Ahsan 2010). Scope problems occurs when the boundary of the system is ill-defined where unnecessary information is given and more important information are left out. According to Savant Institute, "56% of errors in installed systems were due to poor communication between user and analyst in defining requirements and that these types of errors were the most expensive to correct using up to 82% of available staff time". As a result, if requirements are not fully understood then, such requirements will be ambiguous, incomplete, inconsistent, which in turn can negatively affect the success of any project. Finally, customers' needs sometimes change over time, which in turn will affect the stability of the elicited requirements. Such changes in requirements are related to the fact that the analysts and customers do not work together in an effective manner to fully understand existing systems and the necessary functionalities by these systems. "They often have unrealistic expectations of either the functionality that can be provided, or of the time scale in which the system can be developed". If these expectations are not considered at an early point during the elicitation process, then they may lead to unsuccessful project that can fail with a considerable amount of monetary loss.

Sharma and Pandey (2014) have discussed some issues related to requirements elicitation. Conversational method such as interviews sometimes consists of asking a number of questions where some keywords are repeated in these questions, which in turn can cause different people interpret these keywords in different ways. This is more known as a social context problem (Umber, Naweed et al. 2012). Collaborative technique "which systematically combines conversation, observation, and analysis into single methods for developing requirement", also has some issues when it comes to communicating embedded knowledge during requirements elicitation. Contextual techniques, which try to "understand the application domain by observing human activities", also have some issues when it comes to requirements elicitation such as time limitation and awareness about the environment. Finally, cognitive techniques, which are developed for knowledge acquisition, also have their own limitations when it comes to requirements elicitations such as effectiveness of the technique is only dependent on proper documentation and expert's knowledge only (Sharma and Pandey 2014).

Other problem with requirements elicitation have been identified by Tsumaki and Tamai (2006), where the authors have categorized these problem into incomplete requirements, matching requirements elicitation techniques to project characteristics, incorrect requirements, ambiguous requirements, inconsistent requirements, unfixed requirements, and excessive requirements. Where the reasons behind these problems is related to incomplete understanding of needs, incomplete domain knowledge, poor users' collaboration, overlooking tacit assumptions, ill-defined system boundary, misunderstanding of system purpose, synonymous and homonymous terms, un-testable terms, un-solid intentions of requesters, different views of different users, fluctuating requirements, continuous acceptance of additional requirements, unorganized bulky information source, too many requesters, and unnecessary design consideration.

Overall, problem with requirements elicitation can be considered as problems with social and technical aspects of the system under development. Such problems are related to skills, domain, understating of the system boundaries, incomplete understanding of needs, scope, lack of knowledge, poor users' collaboration, different views of different users, changing requirements, poor communication, processes, unnecessary design consideration, complexity, tools, techniques, and methods.

**Requirement Elicitations for Socio-Technical Systems**

Many techniques and methodologies including the *i** notation (Mylopoulos, Chung et al. 1992, Jones and Maiden 2005), scenarios and walkthrough (Mavin and Maiden 2003), and other methods focused on ST and soft approaches have been used for requirements elicitation, analysis, and design for ST system. Jones and Maiden (2005) have proposed a process model called RESCUE for specifying complex ST systems requirements. The RESCUE process is based on a combination of *i** notation, systematic scenario walkthroughs, and best practice in requirements management. The RESCUE process is used in the domain of air traffic control, where development of the systems is evolutionary rather than revolutionary, and the focus is on getting the right requirements rather than speeding up the process. The *i** notation is used and applied in the design and analysis of ST systems. The *i** notation is used to analyze the relationships between the users and systems as demonstrated by Mylopoulos, Chung et al. (1992), where an *i** framework is has been developed to investigate the relationships between requirements goals, agents and tasks.

Bryl, Giorgini et al. (2009) proposed a tool-supported process of requirements analysis for ST systems. The proposed tool is based on planning techniques for exploring the space of requirements alternatives. The tool-supported process helps designer in exploring and evaluating alternative configurations of ST system delegations. This can be done through the use of artificial intelligence planning techniques in order to build a set of design alternatives, and use a set of evaluation criteria to measure and compare the available options. ST walkthrough (STWT) has been used by Herrmann (2009) in order to overcome the integration problem between the technical function of the system with the social structure and perspectives by appropriate guidance for conducting workshops and by means of documentation.

Scenarios have been increasingly used for requirements engineering in which they are used to discover complex ST systems requirements. Mavin and Maiden (2003) used a scenario approach called CREWS-SAVRE to determine requirements for naval and air traffic management systems. Effective structured scenario walkthroughs in addition to the level of domain-specificity can help determine the necessary requirements for such systems.

Machado, Borges et al. (2008) proposed a new approach based a combination of cognitive and observation techniques that can help enhance requirements elicitation process and results in an improved quality of requirements at dynamic, complex and ST workplaces. Another approach is a scenario-based requirements engineering method, where a modeling language is used to describe scenarios, and heuristics are used to check dependencies among scenario models as well as requirements specification. Heuristics are grouped as treatments that analyze the relationships between users' goals and system functions (Sutcliffe 1998). Scenarios have been also used to generate system requirements based on the combinations of scenario scripts, early prototypes, and design rationale in order to collect users' requirements (Sutcliffe and Minocha 1999).

**Literature Summary**

Domain knowledge is considered one of the important attributes when it comes the success of the requirements elicitation process. Expanding analysts' domain knowledge can result in a more acceptable and successful systems. Also, requirements analysis requires analysts to be familiar with the problem domain under study. Sometimes analysts have the necessary experience in systems development, on the other, the knowledge they have about the problem domain is usually limited.

In literature, most studies have addressed the analysts' domain knowledge by using a number of techniques, such technique include ontologies, focus groups, goal oriented modeling method, pattern language to transfer domain knowledge, prototyping, rule-based approach. No study has addressed domain knowledge from a socio-technical perspective.

Analyst "from traditional software engineering backgrounds may sometimes focus on the solution not the problem, and reply on only those techniques they are familiar with for all situations". However, in some cases, it is necessary to investigate and examine the application domain in which the system will reside, where such investigation should account for the technical, political, organizational, and social aspects related to the system aspects.

Many of Challenges and issues related to requirements elicitation are socio-technical in nature and has a strong connection with the notion of socio-technical systems. In addition, most of the techniques used to elicit requirement for socio-technical systems are not based on the socio-technical model for socio-technical system analyses and design.

In the socio-technical system literature, there is a lack of a midrange theoretical model for STS analysis and design. The studies we have about socio-technical system design are very abstract and do not provide any artifact, specific steps, or process for the purpose of practicing socio-technical system analysis and design.

# CHAPTER 3

# SYSTEM DESIGN (RESEARCH METHODOLOGY)

## Design Science Research Methodology

Design science research aims at creating and evaluating information technology (IT) artifacts that are intended to solve important organizational problems (Hevner, March et al. 2004). Design science research methodology involves a rigorous process used to design and develop a design artifacts that can be used to solve observed problems, make research contributions, evaluate the designs, and to communicate the results to appropriate audiences (Hevner, March et al. 2004, Peffers, Tuunanen et al. 2007). Design science research artifacts may include "constructs, models, methods, and instantiations" (Hevner, March et al. 2004). "They might also include social innovations" (Aken 2004, Peffers, Tuunanen et al. 2007) or "new properties of technical, social, and/or informational resources" (Järvinen 2007, Peffers, Tuunanen et al. 2007); in short, "this definition includes any designed object with an embedded solution to an understood research problem".

The research presented here follows the principles of design science by Peffers, Tuunanen et al. (2007). Design science is one side in the information systems research cycle (Hevner, March et al. 2004, Niederman and March 2012) that seeks the creation and evaluation of design artifacts such as conceptual models and software systems (vom Brocke, Riedl et al. 2013) and the development of new generalizable knowledge about design processes and products (Piirainen and Briggs 2011), while solving important problems with these artifacts and knowledge (Hevner, March et al. 2004). The research approach we employed in this work as demonstrated in figure 2 including problem identification, solution objectives, artifact design, demonstration, evaluation, and communication.

Using interviews as a method for requirements elicitation, analysts' experience does not appear to be a relevant factor (Davis, Dieste et al. 2006). The lack of important knowledge about problem domain can affect the quality of the interview questions to be asked in order to collect the necessary requirements. In addition, the analysts should account for the intrinsic and interrelated characteristics of the social and technical aspects of the systems. Such account, also require analysts to be familiar with the problem domain.

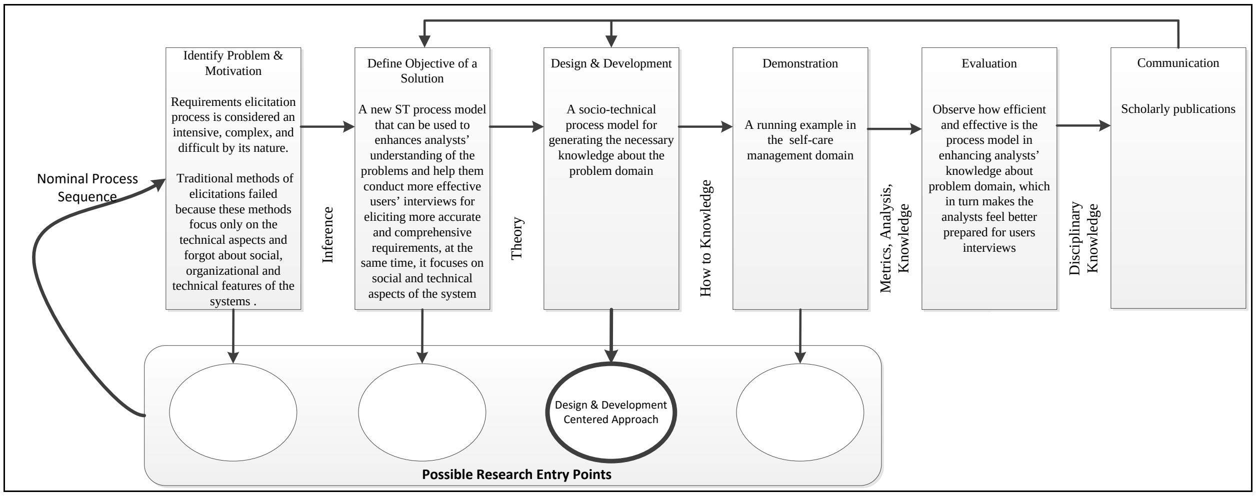


Figure 2. Design Science Approach by Peffers, Tuunanen et al. (2007)

The ST model components can help enhance analysts' domain knowledge and understanding by exploring the relationships between these components. Such understanding and enhanced analysts' knowledge will affect the quality of questions the analysts will ask during the interview process, which in turn will affect the quality of the elicited requirements. The so called ST system theory as well as an extensive literature review will serve as a theoretical foundation for developing a new process model for enhancing analysts' domain knowledge.

Once the proposed ST process model is developed and applied, the resultant artifact will be tested for its feasibility in the self-care domain, where the objective is show how such process model can help improve the analysts' skills and understanding of the problem domain. Evaluation consists of observing and measuring how the outcome from the process model supports the solution to the problem. An empirical investigation, to assess the extent to which the constructed ST process model helps the analysts preparing for the interview, is carried out. Such experimental investigation consists of hypothesis development, variable measurement, experimental design and data collection, and data analysis.

Preliminary demonstration and results of how socio-technical systems model can help in defining system requirements are reported in Sarnikar, El-Gayar et al. (2014). In this work, the researchers developed a ST process model for eliciting ST systems requirement's based on the notion of ST system theory. The process model assumes that ST systems characteristics of tasks, actors, technologies, and environment can help identifying a set of ST imbalances that in turn helps in the identification process of requirements. The proposed process model provides a systematic, comprehensive, and generalizable approach to capture imbalances commonly found in ST systems which in turn can help identifying important ST systems requirements.

Table 3. Design Science Research Methodology by Peffers, Tuunanen et al. (2007)

| **Design Science Activities** | **Research Activities** |
|---|---|
| Problem identification and motivation: Define the specific research problem and justify the value of a solution. | Socio-Technical systems requirements analysis is considered complex, time consuming, and requires a large body of knowledge. Interviews' questions are largely dependent on the analysts' skills and experience. In some cases, interviews may consist of unnecessary questions that can lead to eliciting the wrong requirements. Also, empirical studies showed that careful preparation of interviews has a much more marked effect than analyst experience. Analyst "from traditional software engineering backgrounds may sometimes focus on the solution not the problem, and reply on only those techniques they are familiar with for all situations". In some cases, it is necessary to investigate and examine the application domain in which the system will reside. Such investigation should not be limited to technical aspects of the problem domain but should also include the political, organizational, and social aspects related to the system. Finally, there is a lack of a midrange theoretical model for STS analysis and design |
| Define the objectives for a solution: Infer the objectives of a solution from the problem definition and | Develop a Socio-Technical (ST) process model that can help providing a new midrange theoretical model for ST |

| | |
|---|---|
| knowledge of what is possible and feasible | analysis and design, account for social and technical aspects of systems, and improves analysts' knowledge. |
| Design and development: create the artifact. Such artifacts are potentially constructs, models, methods, or instantiations, or a new properties of technical, social, and/or informational resources | A Socio-Technical process model for generating the necessary knowledge about the problem domain. |
| Demonstration: Demonstrate the use of the artifact to solve one or more instances of the problem. This could involve its use in experimentation, simulation, case study, proof, or other appropriate activity | A running example in the self-care management domain. |
| Evaluation: observe and measure how well the artifact supports a solution to the problem. This activity involves comparing the objectives of a solution to actual observed results from use of the artifact in the demonstration. | Evaluation of the Socio-Technical (ST) process model is done using scientific experimentation to verify the impact of the proposed ST process model on interviews questionnaire development |
| Communication: communicate the problem and its importance, the artifact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences, such as practicing professionals, when appropriate | A number of scholarly publication that demonstrate the effectiveness of the Socio-Technical model in system development. |

## Building the ST System: A STS Based Process Model

In this section we discuss the proposed socio-technical process model as well as explain the different steps that are necessary to apply the new process model for improving analysts' domain knowledge, readiness, and preparations for the requirements analysis phase.

### *Running example:*

Self-care is defined as "*The practice of activities that individuals personally initiate and perform on their own behalf in maintaining life, health, and well-being*" (Kearney and Fleischer 1979). Advances in information technology (IT) have resulted in different solutions that are used to support self-care and management for healthy individuals as well as patients with chronic conditions. However, despite these advances, the adoption and diffusion of these solutions into practice is limited.

Demonstration of the proposed socio-technical process model is carried out in the domain of self-care as a running example. The socio-technical model will serve as a foundation for building a web-based system where the components of the model, namely task, actor, technology, and structure, are used to define the appropriate properties related to the domain of self-care, which in turn are used to define a set of imbalances for self-care systems, and finally the imbalances can help improve analysts understanding of the problem domain.

### *Process Model*

The socio-technical model and imbalances can help the analysts in the requirements analysis phase. Figure 3, shows the proposed ST process model. The proposed approach starts with the socio-technical model described by (Lyytinen and Newman 2008). For each component of the socio-technical model, a list of relevant attributes is identified from literature. Once identified, imbalances between the socio-technical components are identified. Since each of the components are defined using a list of attributes, imbalance are identified among the combinations of the socio-technical components' attributes. The literature is then used to confirm that the list of imbalances exists in relevant systems. Finally, using the identified imbalances and the screened imbalances from the literature, we enriched the target domain with ST knowledge.

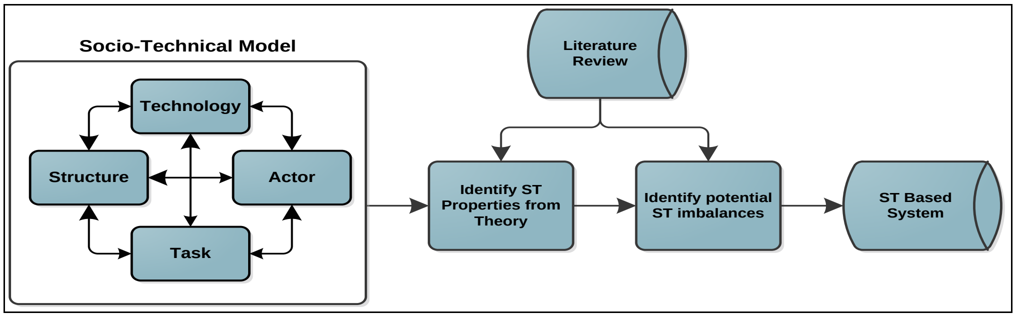


Figure 3. Socio-technical System Process Model for Building the ST Based System

As a starting point and according to the proposed socio-technical requirements elicitation approach, the socio-technical dimensions for self-care processes are defined using Leavitt's model for organizational change and its adaptation (Leavitt 1964, Kwon and Zmud 1987, Lyytinen and Newman 2008). A new socio-technical model for IT-enabled self-care systems has been identified by reviewing relevant literature, coding and categorizing literature findings and relevant self-care concepts along the four socio-technical model components. A summary of the proposed socio-technical model is presented in table 4.

The process proceeds by identifying socio-technical imbalances at the attributes level of the socio-technical model components. Therefore, a list of relevant attributes for heath IT applications are identified for each component based on extensive literature review and grounded in relevant information system theories. These theories include technology acceptance model, unified theory of acceptance and use of technology, social learning theory, and diffusion of innovation theory. From each theory, the relevant components have been identified based on whether they are relevant to each of the ST component or not. For example, the ease of use and usefulness are widely known characteristics of technologies, so they have been defined as the technology component properties. Detailed description about these components properties is presented in table 5.

Table 4. The Socio-Technical Model for IT Enabled Self-Care Systems (El-Gayar, Sarnikar et al. 2013)

| | Work System | Building System | Environment | Main Properties |
|---|---|---|---|---|
| **Task** | Medical therapy, lifestyle changes, symptom monitoring etc. | Self-care processes such as self-glucose monitoring, diet and exercise control etc. | Health maintenance and improvement | Complexity (Cognitive), importance to health maintenance, difficulty (resistance to change, unpleasantness, etc.), frequency, and costs. |
| **Actors** | Patients and healthy persons | Family, care givers, clinicians, friends, and support groups. | Society and payers | Skills, knowledge, perceived health status, self-efficacy, expectations, beliefs. Social and family support, beliefs and motivation, cognitive function, experience, and knowledge. |
| **Structure** | Personal routines within which self-care is embedded | Family and health marketplace structure within which personal routines exists. | Societal and health system structure. | Communication processes, authority, workflows, economics, appropriate and knowledge sources. |
| **Technology** | Devices such as pedometers, glucose meters etc. | Home electronic devices and software such as smart phones and personal computers, and health organization IT infrastructure | Societal IT infrastructure | Functionality, interoperability and usability |

Table 5. ST Model Components Properties

| Task Properties | Definition |
|---|---|
| Importance to health maintenance | Defined as whether performance of the tasks is critical to the maintenance of patient health (Hogan, Hogan et al. 1984) |
| Resources | Defined in terms of task frequency, resources needed to perform the task, the cost of the task, or time required performing the tasks |
| Difficulty | Task difficulty encompasses the degree of “(non)-routineness”, structuredness, and analyzability (Gebauer, Shaw et al. 2005) |
| Interdependence | The task interdependence is the degree to which a task is related to other tasks and the extent to which coordination with other entity is required (Kiggundu 1981) |

| Actor Properties | Definition |
|---|---|
| Knowledge and Expectations | Knowledge is defined as a “body of facts and principles that is learned through life experience, or is taught” (Fredericks, Guruge et al. 2010)<br>An outcome expectation is defined as a “person’s estimate that a given behavior will lead to certain outcomes” (Bandura and McClelland 1977) |
| Self-efficacy | Self-efficacy is “people’s perception of their ability to plan and take action to reach a particular goal” (Bandura 1977, Bandura 1994). |
| Attitude | Attitude is defined as an “affective or evaluative judgment of some person, object, or event” (Barki and Hartwick 1994). |
| Subjective Norm (Social/family support | Subjective Norm is defined as the person’s perception that most people who are important to him/her think that he/she should or should not perform the behavior in questions (Fishbein and Ajzen 1975, Venkatesh, Morris et al. 2003) |

| Structure Properties | Definition |
|---|---|
| Communication processes | Communication is defined in terms of systems of communication, as well as means and channels of communication (Lyytinen and Newman 2008). |
| Authority | Classically defined as "the right to influence and direct behavior, such right having been accepted as valid and legitimate by others in the relationship". In the medical context, authority is defined as the "patient's grant of legitimacy to the physician's exercise of power, on the assumption that it will be benevolent" (Haug and Lavin 1981) |
| Workflows | Workflow is defined as the "automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules" (Sadiq, Marjanovic et al. 2000) |
| Economics | Economics is defined as the financial consideration associated with both health and health care as a good or service that is manufactured, or produced |

| Technology Properties | Definition |
|---|---|
| Functionality | Defined as the ability of technology to perform specific functions (Galloway 2006) |
| Usefulness | Defined as "the degree to which a person believes that using a particular system would enhance his or her job performance (Davis 1989). |
| Usability | Defined as "the degree to which a person believes that using a particular system would be free of effort" (Davis 1989) |

The socio-technical components' properties are used to identify imbalances or gaps. Task-Actor gaps are related to attributes that influence people's ability to perform a task, the task-structure gaps arise when the structure's components are not aligned with the task, the task-technology gaps arise when technology is not adequate to support the tasks, and actor-technology gaps occur when any of the identified actors do not understand, cannot operate, or do not accept the technology, and finally, the actor-structure gaps occur when actors do not know the operating procedures and do not accept the structure. The list of imbalances represents the gaps that need to be addressed in the design of the new socio-technical systems. Example list of identified socio-technical imbalances for the socio-technical components combination are presented in tables 6-11. The list of identified imbalances is supported by evidence from the literature as shown in the tables.

Table 6. Task-Actor Imbalances and Examples

| Task-Actor | Importance to health maintenance | Resources | Difficulty | Interdependence |
|---|---|---|---|---|
| **Knowledge and Expectations** | Imbalances related to actors’ knowledge and expectations, and importance of a task health maintenance | Imbalances related to actors’ knowledge and expectations, and frequency, cost, or time required performing the tasks. | Imbalances related to actors’ knowledge and expectations, and the degree of task’s (non)-routineness, structuredness, and analyzability. | Imbalances related to actors’ knowledge and expectations, and the degree to which a task is related to other tasks and the extent to which coordination with other organizational entities. |
| **Examples** | Patients are unable to meet the expectations of health care providers and fulfilling self-care responsibilities important for maintaining patient’s health (Harris, Wysocki et al. 2000) | Unrealistic patient expectations and demands can make evidence based cost less effective and efficient (Wagner, Austin et al. 1996) | Expectations for self-care autonomy exceeding the patients' cognitive and behavioral capabilities may compromise adherence and diabetic control (Wysocki, Taylor et al. 1996) | Despite recent improvements in glucose control in adults with diabetes [2], <15% of adults with diabetes simultaneously met the goal for three important components of care (i.e., glucose, blood pressure and low-density |

| | | | | |
|---|---|---|---|---|
| | | | | lipoproteins (LDL) cholesterol) (Nam, Chesla et al. 2011) |
| **Self-efficacy** | Imbalances related to actors' self-efficacy, and perception about the importance of a task to health maintenance | Imbalances related to actors' self-efficacy, and frequency, cost, or time required to perform the tasks. | Imbalances related to actors' self-efficacy, and the degree of task's (non)-routineness, structuredness, and analyzability. | Imbalances related to actors' self-efficacy, and the degree to which a task is related to other tasks and the extent to which coordination with other organizational entities. |
| **Examples** | Barriers to adherence and problem-solving skills can play a major role in affecting ongoing self-management of chronic disease (Toobert, Strycker et al. 2002) | Patients are not able to keep on top of needing different medication at different time – scheduling and coordination of medication (Bayliss, Steiner et al. 2003) | Due to differences in technical skills, abilities and learning styles, patients find it difficult to perform specific tasks because they did not gain a comprehensive knowledge of how to perform these tasks (Siobhan, Asma et al. 2012) | Literacy, numeracy (numerical literacy), and health literacy are typically weak in these communities, and people may have a poor sense of autonomy and control over their environments and low self-efficacy for behavior change (Ershow 2009) |

| | | | | |
|---|---|---|---|---|
| **Attitude** | Imbalances related to actors mental or neural state of readiness, and the importance of a task to health maintenance | Imbalances related to actors mental or neural state of readiness, and task frequency, cost of the task, or time required performing the tasks. | Imbalances related to actors mental or neural state of readiness, and the degree of task's (non)-routineness, structuredness, and analyzability. | Imbalances related to actors mental or neural state of readiness, the extent to which coordination with other organizational entities. |
| **Examples** | Adoption and maintenance of health behaviors are often poorly predicted by behavioral intentions (Schwarzer, Schüz et al. 2007) | The lack of financial support for IT applications is a major barrier to adoption (Anderson 2007) | Negative attitude toward insulin therapy is associated with a general lack of understanding of the progressive nature of diabetes (Marrero 2007). | Negative patient attitude toward insulin may be due to a reluctance to add yet another medication to their daily regimen (Marrero 2007) |
| **Subjective Norm (Social/family support** | Imbalances related to actors perception that most people who are important to him think that he should or should not perform the task, and the importance of a task to health maintenance | Imbalances related to actors perception that most people who are important to him think that he should or should not perform the task, and task frequency, cost of the | Imbalances related to actors perception that most people who are important to him think that he should or should not perform the task, and the degree of task's (non)-routineness, | Imbalances related to actors perception that most people who are important to him think that he should or should not perform the task, and the degree to which a task is related to other tasks |

| | | | | |
|---|---|---|---|---|
| | | task, or time required performing the tasks. | structuredness, and analyzability. | and the extent to which coordination with other organizational entities. |
| **Examples** | Low family support prevent patients from performing the necessary self-management tasks (Richard and Shea 2011). | Lower frequency of self-monitoring blood glucose (SMBG)is associated with the lack of family support that negatively affect adherence for SMBG (Fisher 2007). | Diabetes patients show that low support from their family was associated with making their diabetes more serious (Skinner, John et al. 2000) | Results indicated that the nurse-facilitated social support group achieved higher levels of patient blood pressure control compared to a lecture group and control group which received usual or standard office care (Morisky, DeMuth et al. 1985) |

Table 7. Task-Structure Imbalances and Examples

| Task-Structure | Importance to health maintenance | Resources | Difficulty | Interdependence |
|---|---|---|---|---|
| **Communication processes** | Imbalances related to actors' perception about the importance of a task to maintenance of health, and means and channels of communication | Imbalances related to actors' perception of task frequency, cost of the task, or time required performing the tasks, and means and channels of communication | Imbalances related to actors' perception of task's (non)-routineness, structuredness, and analyzability, and means and channels of communication | Imbalances related to actors' perception of how a task is related to other tasks and the extent to which coordination with other organizational entities, and means and channels of communication |
| **Examples** | Patients, with poor functional health literacy have difficulties reading and comprehending written medical instructions, are more likely to be confused or under informed about their condition and the | Patients do not receive the adequate services from heath care providers because such providers fail to take into account the potential cost benefits of improving communication with their | Patients with low functional health literacy may also have difficulties with oral communication with providers (Samantha Garbers and Chiasson 2004) | Task interdependence constrains the interactions among team members and the extent to which they need to coordinate their individual responses (Katz-Navon and Erez 2005) |

| | | | | |
|---|---|---|---|---|
| | processes of care required to successfully manage it (Schillinger, Bindman et al. 2004)<br><br>key factors that affects the acceptability of medicine among patients is the communication styles that may differ among health providers and linguistic barriers (Glanz, Croyle et al. 2003) | patients (Jacobs, Shepard et al. 2004). | | |
| **Authority** | Imbalances related to actors' perception about the importance of a task to maintenance of health, and the patient's grant of legitimacy to the physician's exercise of power | Imbalances related to actors' perception of task frequency, cost of the task, or time required performing the tasks, and the patient's grant of legitimacy to the | Imbalances related to actors' perception of task's (non)-routineness, structuredness, and analyzability, and the patient's grant of legitimacy to the | Imbalances related to actors' perception of how a task is related to other tasks and the extent to which coordination with other organizational entities, and the patient's grant of legitimacy to the |

| | | | | |
|---|---|---|---|---|
| | | physician's exercise of power | physician's exercise of power | physician's exercise of power |
| **Examples** | NA | NA | NA | NA |
| **Workflows** | Imbalances related to actors' perception about the importance of a task to maintenance of health, and existing workflows | Imbalances related to actors' perception of task frequency, cost of the task, or time required performing the tasks, and existing workflows | Imbalances related to actors' perception of task's (non)-routineness, structuredness, and analyzability, and systems that specify, execute, monitor, and existing workflows | Imbalances related to actors' perception of how a task is related to other tasks and the extent to which coordination with other organizational entities, and existing workflows |
| **Examples** | Problems affecting existing workflows can result in a complex and lengthy process of medication ordering, especially in the time of admission, discharge and transfer, which is something importance to | The need to procure supplies and equipment not available in the workspace can results in disruption in workflow (Brixey, Robinson et al. 2007) To identify workflow bottlenecks and efficiencies currently | A major difficulty in the emergency room is the number of interruptions that affected the workflow in the unit(Murphy, Reddy et al. 2014) | NA |

| | | | | |
|---|---|---|---|---|
| | health (Niazkhani, Pirnejad et al. 2009) | requires costly, labor intensive time-and-motion studies(Elnahrawy and Martin 2010) | | |
| **Economics** | Imbalances related to actors' perception about the importance of a task to maintenance of health, and financial considerations related to self-care | Imbalances related to actors' perception of task frequency, cost of the task, or time required performing the tasks, and financial considerations related to self-care | Imbalances related to actors' perception of task's (non)-routineness, structuredness, and analyzability, and financial considerations related to self-care | Imbalances related to actors' perception of how a task is related to other tasks and the extent to which coordination with other organizational units is required, and financial considerations related to self-care |
| **Examples** | NA | Economics burden of chronic diseases is a function of the cost of hospitalizations, which occur more frequently in elderly patients (Berry, Murdoch et al. 2001) | NA | NA |

Table 8. Task-Technology Imbalances and Examples

| **Task-Technology** | **Importance to health maintenance** | **Resources** | **Difficulty** | **Interdependence** |
|---|---|---|---|---|
| **Functionality** | Imbalances related to actors' perception about the importance of a task to maintenance of health, and the actors' perception that a device performed specific functions | Imbalances related to actors' perception of task frequency, cost of the task, or time required performing the tasks, and the actors' perception that a device performed specific functions | Imbalances related to actors' perception of task's (non)-routineness, structuredness, and analyzability, and the actors' perception that a device performed specific functions | Imbalances related to actors' perception of how a task is related to other tasks and the extent to which coordination with other organizational entities, and the actors' perception that a device performed specific functions |
| **Examples** | Modern medicine and health care systems suffers from limitations for improving the health status of the population (Bhuyan 2004) | NA | Due to differences in technical skills, abilities and learning styles, patients find it difficult to perform specific tasks because they did not gain a comprehensive knowledge of how to | NA |

| | | | | |
|---|---|---|---|---|
| | | | perform these tasks (Siobhan, Asma et al. 2012). | |
| **Usefulness** | Imbalances related to actors' perception about the importance of a task to maintenance of health, and the actors' perception that using a particular system would enhance his or her job performance | Imbalances related to actors' perception of task frequency, cost of the task, or time required performing the tasks, and the actors' perception that using a particular system would enhance his or her job performance | Imbalances related to actors' perception of task's (non)-routineness, structuredness, and analyzability, and the actors' perception that using a particular system would enhance his or her job performance | Imbalances related to actors' perception of how a task is related to other tasks and the extent to which coordination with other organizational entities, and the actors' perception that using a particular system would particular system would enhance his or her job performance |
| **Examples** | Patients reported that the glucometer would lose its date-time stamp when cleaned or when the batteries fell out accidentally during handling, thus making | NA | NA | Benefits of mobile applications in relation to data access and integration are not easily realized because the core applications of the system are not fully integrated |

| | | | | |
|---|---|---|---|---|
| | them useless (Keshavjee, Lawson et al. 2003) | | | (Standing and Standing 2008) |
| **Usability** | Imbalances related to actors' perception about the importance of a task to maintenance of health, and the actors' perception that using a particular system would be free of effort | Imbalances related to actors' perception of task frequency, cost of the task, or time required performing the tasks, and the actors' perception that using a particular system would be free of effort | Imbalances related to actors' perception of task's (non)-routineness, structuredness, and analyzability, and systems that specify, execute, monitor, and the actors' perception that using a particular system would be free of effort | Imbalances related to actors' perception of how a task is related to other tasks and the extent to which coordination with other organizational entities, and the actors' perception that using a particular system would be free of effort |
| **Examples** | Patient find that the home technology units were difficult to use (Baig, Wilkes et al. 2010) | The Computerized Patient Portals is difficult to use by patients because it requires too long time to learn (Zickmund, Hess et al. 2008) | Patients satisfied with the communication with her physician found the system too difficult to use because its time consuming (Zickmund, Hess et al. 2008) | The home technology used a telephone line and was reported to be easy to use, but it required a partnership with a health care system that utilized an EMR (Baig, Wilkes et al. 2010) |

Table 9. Actor-Structure Imbalances and Examples

| Actor-Structure | Knowledge and Expectations | Self-efficacy | Attitude | Subjective Norm (Social/family support |
|---|---|---|---|---|
| **Communication processes** | Imbalances related to actors' knowledge and expectations, and means and channels of communication | Imbalances related to actors' self-efficacy, and means and channels of communication | Imbalances related to actors mental or neural state of readiness, and means and channels of communication | Imbalances related to actors perception that most people who are important to him think that he should or should not perform the task, and means and channels of communication |
| **Examples** | Elderly patients may find it difficult to use and interpret the information provided to them by their smartphone (Ozdalga, Ozdalga, & Ahuja, 2012). | Problems in patient-healthcare provider communication process are related to fundamental skills in effective communication with diverse populations (Horner, Salazar et al. 2004) | Several descriptive studies provide consistent evidence that people who use email would like email access to their doctors (Car and Sheikh 2004) | Patents perceived poor physician communication as well as low family support as barriers to active self-management of chronic conditions (Jerant, Friederichs-Fitzwater et al. 2005). |

| | | | | |
|---|---|---|---|---|
| **Authority** | Imbalances related to actors’ knowledge and expectations, and the patient's grant of legitimacy to the physician's exercise of power | Imbalances related to actors’ self-efficacy, and the patient's grant of legitimacy to the physician's exercise of power | Imbalances related to actors mental or neural state of readiness, and the patient's grant of legitimacy to the physician's exercise of power | Imbalances related to actors perception that most people who are important to him think that he should or should not perform the task, and the patient's grant of legitimacy to the physician's exercise of power |
| **Examples** | Despite the fact that physicians should educate patients about their conditions, patients lack the necessary knowledge about existing conditions (Cheng, Lichtman et al. 2005) | NA | NA | NA |
| **Workflows** | Imbalances related to actors’ knowledge and | Imbalances related to actors’ self-efficacy, and existing workflows | Imbalances related to actors mental or neural | Imbalances related to actors perception that most people who are |

| | | | | |
|---|---|---|---|---|
| | expectations, and existing workflows | | state of readiness, and existing workflows | important to him think that he should or should not perform the task, and existing workflows |
| **Examples** | NA | NA | NA | NA |
| **Economics** | Imbalances related to actors' knowledge and expectations, and financial considerations related to self-care | Imbalances related to actors' self-efficacy, and financial considerations related to self-care | Imbalances related to actors mental or neural state of readiness, and financial considerations related to self-care | Imbalances related to actors perception that most people who are important to him think that he should or should not perform the task, and financial considerations related to self-care |

Table 10. Actor-Technology Imbalances and Examples

| **Actor-Technology** | **Knowledge and Expectations** | **Self-efficacy** | **Attitude** | **Subjective Norm (Social/family support** |
|---|---|---|---|---|
| **Functionality** | Imbalances related to actors' knowledge and expectations, and the actors' perception that a device performed specific functions | Imbalances related to actors' self-efficacy, and the actors' perception that a device performed specific functions | Imbalances related to actors mental or neural state of readiness, and the actors' perception that a device performed specific functions | Imbalances related to actors perception that most people who are important to him think that he should or should not perform the task, and the actors' perception that a device performed specific functions |
| **Examples** | Continuous glucose sensors do not fulfill patients' the expectations concerning stability, reliability, and accuracy (Diem, Kalt et al. 2004). | Low self-efficacy is considered a major challenge preventing adults from using mobile technologies in performing relevant tasks (Leung, Tang et al. 2012) | Using the functionalities of the handheld devices by patients is not straightforward and not user-friendly (Vuong, Huber Jr et al. 2012) | Family support often ignored in the chronic patients' caring system such as using mobile technology in chronic disease (Azam and Yang 2013) |
| **Usefulness** | Imbalances related to actors' knowledge and | Imbalances related to actors' self-efficacy, and | Imbalances related to actors mental or neural | Imbalances related to actors perception that |

| | | | | |
|---|---|---|---|---|
| | expectations, and the actors' perception that using a particular system would enhance his or her job performance | the actors' perception that using a particular system would enhance his or her job performance | state of readiness, and the actors' perception that using a particular system would enhance his or her job performance | most people who are important to him think that he should or should not perform the task, and the actors' perception that using a particular system would enhance his or her job performance |
| **Examples** | NA | NA | Patients' attitude toward using handheld devices is low because such devices are not useful for saving information in the case of low battery (Vuong, Huber Jr et al. 2012) | NA |
| **Usability** | Imbalances related to actors' knowledge and expectations, and the actors' perception that using a particular system would be free of effort | Imbalances related to actors' self-efficacy, and the actors' perception that using a particular system would be free of effort | Imbalances related to actors mental or neural state of readiness, and the actors' perception that using a particular system would be free of effort | Imbalances related to actors perception that most people who are important to him think that he should or should not perform the task, and |

| | | | | |
|---|---|---|---|---|
| | | | | the actors' perception that using a particular system would be free of effort |
| **Examples** | Accessing the Web-based diabetes care features was not useful because it is a new technology with which participants were unfamiliar (Lyles, Harris et al. 2011) | eRecord may appear to be more difficult to end users, particularly novice computer users, given that more steps are required to document findings when compared to a paper record (Rinkus and Chitwood 2002). | In the e-health domain, technologies are difficult to use and not adapted to the particular needs and thus perceived to be of little utility, they often are ignored (Van Hoecke, Steurbaut et al. 2010) | NA |

Table 11. Structure-Technology Imbalances and Examples

| Structure-Technology | Communication processes | Authority | Workflows | Economics |
| --- | --- | --- | --- | --- |
| **Functionality** | Imbalances related to actors’ perception that a device performed specific functions, and means and channels of communication | Imbalances related to actors’ perception that a device performed specific functions, and the patient's grant of legitimacy to the physician's exercise of power | Imbalances related to actors’ perception that a device performed specific functions, and existing workflows | Imbalances related to actors’ perception that a device performed specific functions, and financial considerations related to self-care |
| **Examples** | NA | NA | Implementing privacy technologies and procedures results in Negative effects on workflow and work efficiencies in the healthcare context (Murphy, Reddy et al. 2014) | NA |

| | | | | |
|---|---|---|---|---|
| **Usefulness** | Imbalances related to actors' perception that using a particular system would enhance his or her job performance , and means and channels of communication | Imbalances related to actors' perception that using a particular system would enhance his or her job performance, and the patient's grant of legitimacy to the physician's exercise of power | Imbalances related to actors' perception that using a particular system would enhance his or her job performance, and existing workflows | Imbalances related to actors' perception that using a particular system would enhance his or her job performance, and financial considerations related to self-care |
| **Examples** | NA | NA | NA | NA |
| **Usability** | Imbalances related to actors' perception that using a particular system would be free of effort, and means and channels of communication | Imbalances related to actors' perception that using a particular system would be free of effort, and the patient's grant of legitimacy to the physician's exercise of power | Imbalances related to actors' perception that using a particular system would be free of effort, existing workflows | Imbalances related to actors' perception that using a particular system would be free of effort, and financial considerations related to self-care |
| **Examples** | Patients found it difficult to use the Diabetes Interactive Diary system | NA | Usability limitation related to existing systems can affect existing | NA |

| | |
|---|---|
| because they have difficulties in sending text messages (Rossi, Nicolucci et al. 2010). | workflows which in turn results in a complex and lengthy process of medication ordering (Niazkhani, Pirnejad et al. 2009) |

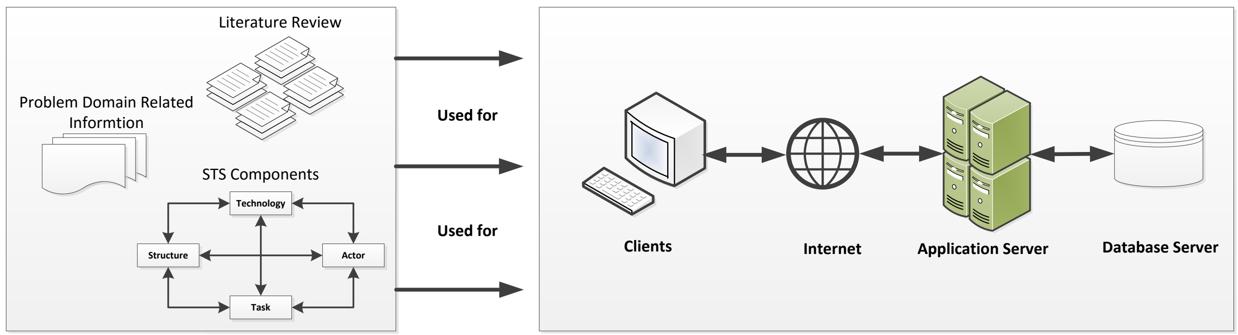


Figure 4. Socio-technical Requirement Elicitation Support System Architecture

For evaluation purposes, we have developed a ST based requirement elicitation support system that consists of all the previously mentioned information. For evaluation purposes, we have included only few imbalances and example on these imbalances. Figure 4 shows the architecture for the proposed ST base system implementation. Using the ST model components, related problem domain information, as well as an extensive literature review related to the problem domain and grounded in the ST theory, we developed a web-based application that can be used by the system analysts. The analysts have the problems for the system; know about particular cases, but not about how the system works or the domain.

# CHAPTER 4

# EVALUATION, RESULTS, AND DISCUSSION

## Assessment Model:

As discussed before, the design of the user interview's questions is considered a critical step in the process of requirements analysis. We argue that the proposed ST requirement elicitation support system model enhances the analysts' domain knowledge and helps them to better prepare for users' interviews. Also, we argue that the ST requirement elicitation support system model will directly enhances the quality of the developed user interview questionnaire.

The subjects in the user study are divided into two different groups, a treatment and control group. The treatment groups will have access to the ST requirement elicitation support system where the control group will use their own experience as well as narrative of the problem statement regarding different kind of requirements, in order to help with systems analysis and design practices in developing the requirement elicitation questionnaire.

## Hypothesis Development:

Access to the ST requirement elicitation support system will distinguish between the treatment group and the control group. The values representing the variable "access to ST based system" are 1 which denotes access to the ST based system by the treatment group and 0 which denotes control group.

The subjects' performance is modelled from two perspectives. The first perspective is to determine how the analysts feel about their understanding of the domain knowledge and how well they are prepared for the requirements analysis interviews (self-assessment perspective). In the self-assessment process, the analysts will evaluate and compare their own knowledge and ability after using the proposed ST based requirement elicitation support system. We argue that access to the ST requirement elicitation support system will increases the analyst's domain knowledge more than those who have not, which also will make the analyst feel better prepared for proceeding with users' interviews.

***H1***: A difference exists between self-reported *domain knowledge* of analysts who have access to the ST requirement elicitation support system and those who have not. Where those who access the system will report higher domain knowledge more than those who have not.

***H2***: A difference exists between self-reported *user interview readiness* of analysts who have accesses the ST requirement elicitation support system and those who have not. Where those who access the system will report higher interview readiness more than those who have not.

The second perspective is the analysts' relative performance. In this perspective, the analyst performance when developing the interview questionnaire is compared for those who have access to the ST requirement elicitation support system (treatment group) and those who do not have access (control group). In order to assess analysts' performance, we need a third party judge (someone who is an expert in the domain of system analysis and design) in order to assess the quality of the interviews questions. In this context, we argue that access to ST requirement elicitation support system will improve the overall performance of the analysts. The analyst' initial domain knowledge is used as a control variable to account for the variability of the domain knowledge at the start of the study.

***H3***: A difference exists between user interview *questionnaire quality* of analysts who have access the ST requirement elicitation support system and those who have not. Where the quality of the questionnaire developed by the analysts will be better for those who have access to the system than those who do not.

**Variable Measurements:**

An instrument is developed based on existing literature (Vitharana, Jain et al. 2012) using existing items used to measure analyst's domain knowledge and self-reported interview readiness. A web-based survey instrument is used to collect data from subjects at different stages of the study.

Semantic differential scales are used to measure each item in the survey for analyst's domain knowledge and self-reported interview readiness. In the typical semantic differentiation task, “a subject judges a series of concepts against a series of bipolar, seven-step scales defined by verbal opposites”. Examples of such verbal opposite can be good-bad, low-high, hot-cold, fair-unfair, etc. (Osgood 1964).

Demographic Information

- Did you take any systems analysis and design or software engineering classes?

  Yes

  No

- Do you have any experience in systems analysis and design or software engineering?

  Yes

  No

- What is Your Age?

  18 to 24

  25 to 34

  35 to 44

  45 to 54

  55 to 64

  65 to 74

  75 or older

- What is Your Gender?

  Male

  Female

- What is Your Level of Education?

  Bachelors’ degree

  Master’s degree

  Professional degree

  Doctorate degree

Analyst's domain knowledge is measured using five-item semantic differential scale anchored as shown below.

As an analyst

- My understanding of the various aspects of the diabetes management is:

Low 1 2 3 4 5 6 7 High

- My understanding of what diabetes management involves is

Low 1 2 3 4 5 6 7 High

- My grasp of the key issues relevant to the diabetes management is

Low 1 2 3 4 5 6 7 High

- My expertise in diabetes management is

Novice 1 2 3 4 5 6 7 Expert

- My ability to answer questions related to diabetes management is

Low 1 2 3 4 5 6 7 High

Analyst's interview readiness is measured using four-item semantic differential scale anchored as shown below.

As an analyst:

- My confidence in being prepared for interviewing the users is

Low 1 2 3 4 5 6 7 High

- My understanding of what to ask the users is

Low 1 2 3 4 5 6 7 High

- My ability to successfully interview the users about their requirements is

Low 1 2 3 4 5 6 7 High

- My level of comfort in interviewing the users could be characterized is

Uncomfortable 1 2 3 4 5 6 7 Comfortable

**Experimental Design and Data Collection:**

In design science research, experimental evaluations evaluate the design artifacts in terms of its utility (Hevner, March et al. 2004, D'Aubeterre, Iyer et al. 2009). Also, it helps in empirically demonstrating the qualities of the artifact (Hevner, March et al. 2004) and allows for generalizing of the findings. Walls, Widmeyer et al. (1992) suggest an experimental design where the performance of the experimental group using the IT artifact is compared against the performance of the control group not using the IT artifact. However, for rigorous purposes, the control groups will use a different IT artifact other than the one used by the treatment group. The experimental design using a treatment and control groups will ensure the rigor of the research in terms of the evaluations of the artifact of the treatment group with the control group one. Also the rigor of the study has been achieved by following rigorous method in the construction of the artifact as well as the evaluation. “Rigor is derived from the effective use of the knowledge base theoretical foundations and research methodologies” (Hevner, March et al. 2004)

We will test the hypothesis empirically using a controlled experiment. A two treatments pretest-posttest design is used to test the effectiveness of the proposed system. The purpose of the pretest is to make sure that all members of both controls and treatment groups have the same level of knowledge with respect to the main tasks of the experiment.

| | | | |
|---|---|---|---|
| **R** | **O** | $X_1$ | **O** |
| **R** | **O** | $X_2$ | **O** |

Figure 5. The Basic Pre-Post Randomized Experimental Design

Figure 5 shows the basic pre-post randomized experimental design. Each row represents a group of subjects, (R) denotes the random assignment of subjects to each group, outcomes (O) are measured before and after the treatment (X1) is assigned to the treatment group and the other treatment (X2) is assigned to the control group.

Using the design in Figure 5 will help avoid the selection bias problem, or what is called selection threat, in which other factors other than the program lead to the post-test differences between the groups (Trochim and Donnelly 2001). It is essential that the subjects assigned to treatment and control groups be representative of the same population (Everitt 2002). In such case, random sampling and random assignment of subjects items from a common population to one of the treatment and control groups (Montgomery 2008) can help make sure that the two groups have similar characteristics and avoid selection threats to internal validity (Trochim and Donnelly 2001).

In this context, random sampling and random assignment are the key to make sure that any differences in the post-test results is related to the treatment and nothing else. A random sample is most likely to distribute any potential biasing characteristics across all the groups being formed through the sampling process (Salkind 2012). On the other side, a stratified random sampling is used when the population contains potential participants who have characteristics that are related to the variable under study (Onwuegbuzie and Leech 2007, Salkind 2012). "Stratified random sampling represents a sampling scheme in which a population is divided into sub-populations such that members of each sub-population are relatively homogeneous with respect to one or more characteristics and relatively heterogeneous from members of all other subgroups with respect to this/these characteristic(s)" (Onwuegbuzie and Leech 2007).

The main task is to develop an interview questionnaire for a diabetes mobile application. The subjects are graduate students at Dakota State University (DSU) with systems analysis and design knowledge. Those who already took any classes related to system and design will be randomly selected to be part of the experiment.

As discussed before, participants are randomly assigned to the treatments and test groups, where the treatment groups access the ST requirement elicitation support system and the control group will use the non-ST based system that consist of a section of the software requirements specification (SRS) document as well as a narrative of the problem statement where the analysts will use their own experience with system analysis and design practices to develop the questionnaire. The SRS template has been modified to show the control group subjects a general definition for the function and non-functional requirements as well as example questions that they can follow to construct the questionnaire. Each of the participants is provided with a description (scenario) about the target mobile diabetes application. Based on the scenario, the participants develop the interview questions while using the ST requirement elicitation support system. At the time of the registration, the data on participant's initial domain knowledge, interview readiness, and participant demographic information are collected. Once the interview questions are ready, participants will fill out the survey on perceived domain knowledge and perceived interview readiness. The quality of interview questionnaires is assessed by two independent raters. Pre-testing and pilot testing of the measures will be conducted by selected students as well as experts in the information systems research area.

## Questionnaire Quality

The quality of the questionnaire is based on metrics adopted from (Browne and Rogich 2001, Pitts and Browne 2007). The process judging the questionnaire quality starts by rating the resulting interviews, where judges are asked to rate each questionnaire using the rubric. The rating process go through an initial assessment of a selected number of questionnaire that go through a number of assessment cycles until all contradiction between the two judges are solved and an acceptable inter-rater reliability achieved. Such assessment is mainly concerned with whether the questions in the questionnaire are relevant or not.

Requirements elicitation involves asking a set of questions as part of the interview session to the target users and stakeholders. A well-known questioning technique is the interrogatories technique, which involves asking "who," "what," "when," "where," "how," and "why"; questions (Gaska and Gause 1998, Browne and Rogich 2001, Pitts and Browne 2007). Such questions can help in better understanding the context and details of a system at different levels of abstraction (Gaska and Gause 1998).

- **What** is questions requesting more information about a requirement. What questions are used to define the objectives and benefits from the system. They describe functionality that must be built into system to enable the users to perform their goals or tasks. They are also related to inputs and outputs of information and materials associated with each task or the user want to perform or achieve. In addition, they are related to a set of features which are considered logically related functional requirements that provides a capability to the user and enables the accomplishment of the user’s task or goal. Also, they are used to describe what information and materials are needed.
- **How** to questions ask how some activity, action or use case is to be performed. How questions are used to describe how the users want to perform goals or tasks. They are also used to describe how the system must perform. In addition, they describe the relationships between business data, the flow of data, and how the data is used to make decisions. They are related to how the information and materials used. This category focuses on procedures and process. They are used to find out HOW does the WHO use the WHAT?

- **Who** questions request confirmation about which stakeholders are responsible for a given action or requirements. Who questions are used to identify the users of the product or system, or performers in the business process. The term user is defined as anyone who affects or is affected by the product. This definition includes people, computer applications, machines, robots, and external systems and interfaces.
- **When** question to know when a process, activity, or feature should start. When questions are related to when users need to perform a task or achieve a goal. Also, they are related to when information and materials are needed. Such kinds of questions are used to find out for each WHY, WHEN does the WHO need the WHAT? WHEN is often associated literally to what time of day. However, WHEN can also refer to the sequence of events, triggers, business cycles, as well as the transformation of states.
- **Why** questions used to know more details about why we need a process, activity or feature. Why questions are related to why users need to perform a task or achieve a goal. Also, they are related to why information and materials are needed. Such kinds of questions are used to find out WHY the WHO needs the WHAT?
- **Where** questions used to know where the activity, action, or feature is used. Where questions are also related to where be the information and materials used. In this category incrementally build upon the previous interests, for each WHO and WHY, WHERE is the WHAT used?

The questionnaires developed by the participants are evaluated along these six dimensions using the following two measures adapted from (Browne and Rogich 2001, Pitts and Browne 2007)

- **Breadth** refers to the number of different questions categories along each dimension
- **Depth** refers to the number of questions obtained within each category

Before using the rubric, the domain expert must examine each question in order to determine whether it is relevant to the problem domain or not. In case a question is not relevant, the domain expert will delete that question from the questionnaire.

Since the analysts will be free to write any questions, then the content of these questions will be analyzed based on the definitions of the "who," "what," "when," "where," "how," and "why" and codes will be assigned to each questions based on these 6 labels.

For each questionnaire the breadth and depth are calculated. Then a mean values are calculated for the breadth and the depth/breadth values for all questionnaires. Such values will be used to do a t-test between the two groups.

**Data Analysis:**

The Multivariate analysis of variance (MANOVA) is used to test the hypotheses. MANOVA is a statistical technique that can be used to simultaneously explore the relationship between several categorical independent variables (usually referred to as treatments) and two or more metric dependent variables.

MANOVA uses the set of metric variables as dependent variables and the objective becomes finding groups of respondent that exhibit differences on the set of dependent variables (Hair). Also, MANOVA is used to solve our Type I error rate problem by providing a single overall test of group differences on all items measuring IT's potential for impact on marketing and on operations (Karimi, Somers et al. 2001, Hair, Black et al. 2010)

According to Hair, Black et al. (2010), using MANOVA, the sample size requirements relate to individual group sizes and not the total sample per se. As practical rules for MANOVA to work, Hair, Black et al. (2010) suggested that at minimum the sample in each cell (group) must be greater than the number of dependent variables. On the other hand, form a practical perspective, they recommended minimum cell size is 20 observations. According to some experiments that has been done with G*Power (Faul 2013, Statistics_Solutions 2013) Power analysis for a MANOVA with two levels and two dependent variables, using an alpha of 0.05, a power of 0.80, and a large effect size ($f = 0.40$) requires a sample size of 28.

In designing the study (Table 12), the research define the following elements related to factors used, dependent variable, and the sample size

- Factors: One factor is defined representing Questionnaire Development Techniques followed, which is represented at two levels, Access to the ST requirement elicitation support system and No Access to the system (analyst uses his/her own experience).
- Dependent Variables: Evaluation is done for two variables (Analyst Domain Knowledge and Analyst Interview Readiness), measured on a 7 point semantic differential scale

- Sample: A minimum of 28 subjects are needed to participate in the experiment and rate the two dependent measures.

Table 12. Data Analysis Design

| **Independent Variable** | **Dependent Variable** | |
|---|---|---|
| **Two Levels** | **Domain Knowledge** | **Interview Readiness** |
| **Treatment (using the proposed system)** | **X** | **X** |
| **Control** | **Y** | **Y** |
| *Where X+Y=N, and N represent the sample size, & X=Y* | | |

**Results**

This section presents the finding from the experiments which include descriptive statistics, hypothesis testing results, as well as the questionnaire quality results.

***Descriptive Statistics***

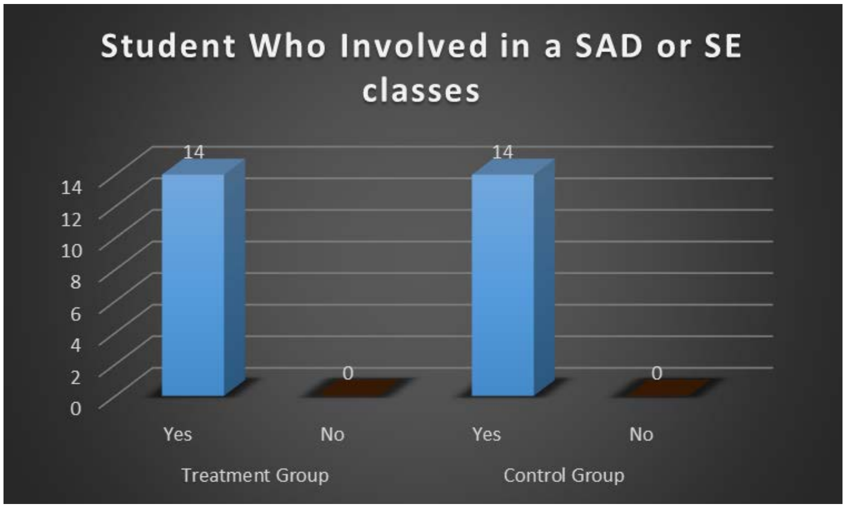


Figure 6. Systems Analysis and Design (SAD) or Software Engineering (SE) classes

Figure 6 shows the number of students who already passed a systems analysis and design (SAD) or software engineering (SE) classes. Based on the selection criteria, we have all subjects in both the treatment group and control group already have taken a class in systems analysis and design (SAD) or software engineering (SE).

Figure 7 shows the number of students who has experience with systems analysis and design (SAD) or software engineering (SE). For treatment group, we have 6 out of 14 subjects have experience with systems analysis and design (SAD) or software engineering (SE). On the other hand, for the control group we have 8 out of 14 subjects have experience with systems analysis and design (SAD) or software engineering (SE).

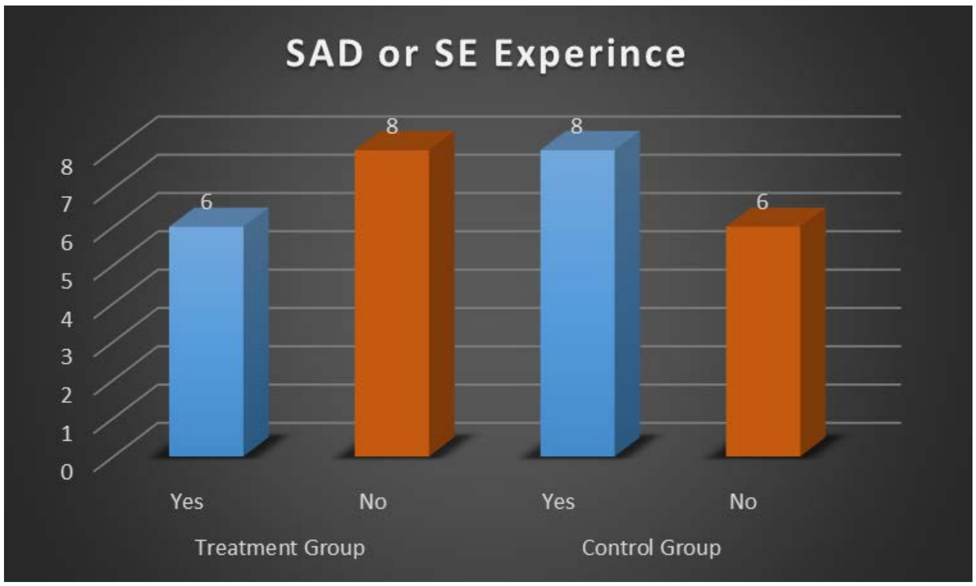


Figure 7. Systems Analysis and Design (SAD) or Software Engineering (SE) Experience

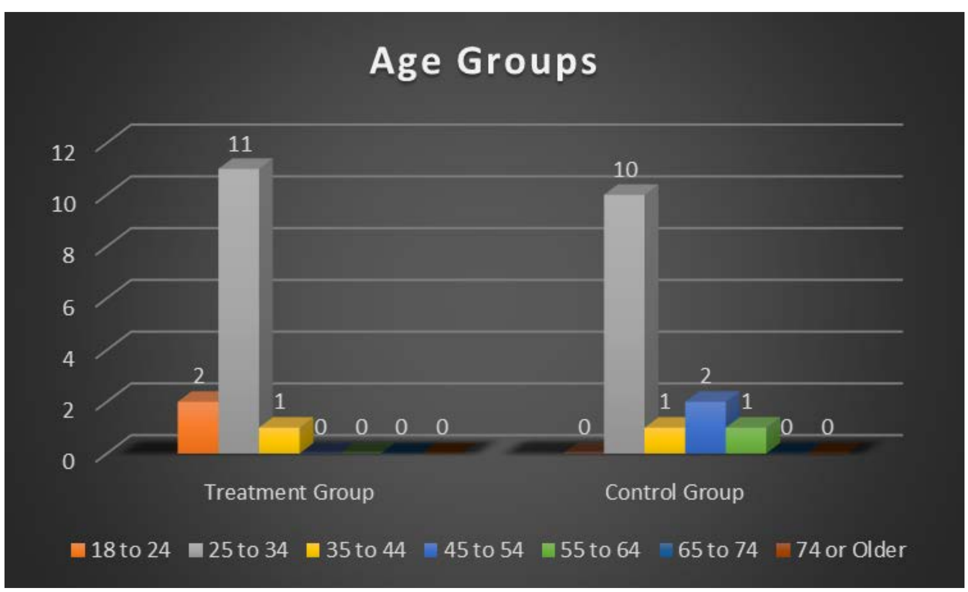


Figure 8. Age Groups across Different Groups

Figure 8 shows the age group distribution among different groups. For treatment group we have 2 subject with age between 18 to 24, 11 subject with age between 25 to 34, and finally 1 subject with age between 35 to 44. On the other hand, for the control group we have 10 subjects with age between 25-34, 1 subject with age between 35 to 44, 2 subjects with age between 45 to 54, and finally, 1 subject with age between 55 to 64.

Figure 9 shows the age group distribution among different groups. For treatment group we have a total of 11 males and 3 females. On the other hand, for the control group we have a total of 14 males and no females.

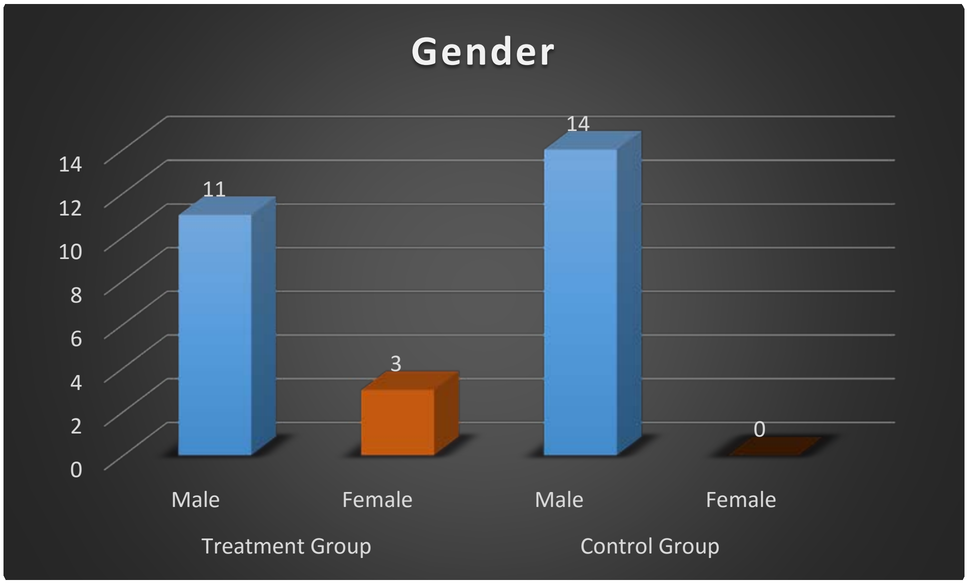


Figure 9. Gender across Different Groups

Figure 10 shows the educational level distribution among different groups. For treatment group we have a total of 8 master’s degree and 6 doctoral degrees. On the other hand, for the control group we have a total of 6 master’s degree, 1 professional degree, and 7 doctoral degrees.

Figure 11 shows the number of students who answered the quiz correctly. The distribution shows each question separately. We have a total of 14 student answered Q1 correctly, 8 student answered Q2 correctly, 9 student answered Q3 correctly, and 11 student answered Q4 correctly.

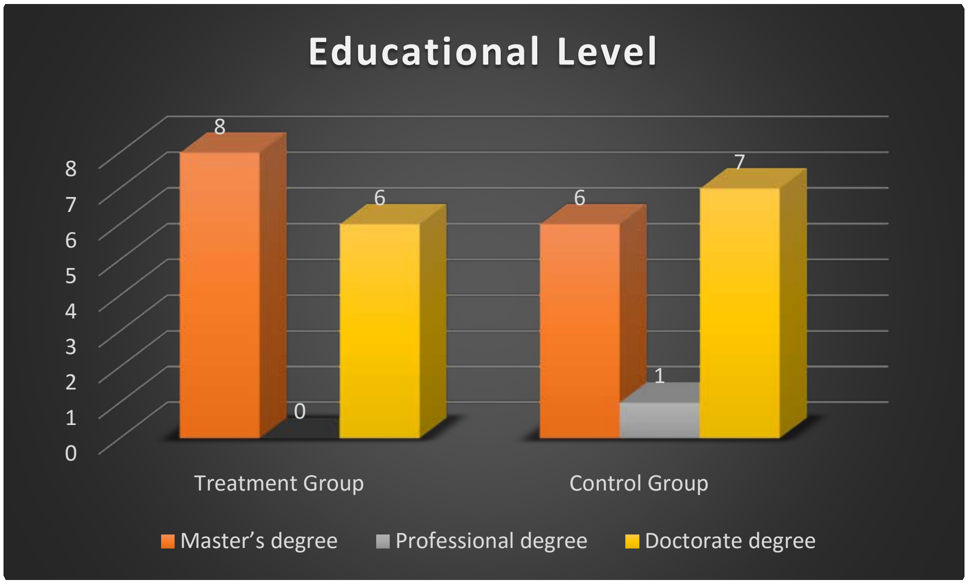


Figure 10. Educational Levels across Different Groups

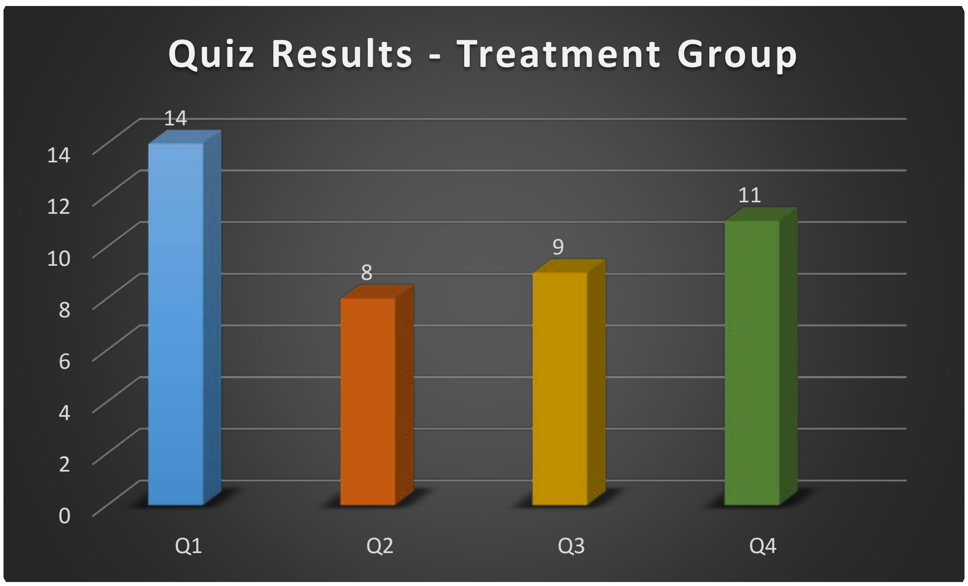


Figure 11. Number of correctly Answered Questions in Treatment Quiz

### *MANOVA Assumptions (Pretest) and Hypothesis Testing*

As mentioned before, the Multivariate analysis of variance (MANOVA) is used to test the hypotheses. We have used MANOVA for both pre-test and posttest. Before proceeding with hypothesis testing, we have conducted different tests to make sure that the main assumptions behind MANOVA hold. These tests for assumptions are described as follow:

***Sample size and homogeneity of variance***

The principal consideration in the design of the two-group MANOVA is the sample size in each of the cells, which directly affects statistical power. Following the previous discussion about sample size for MANOVA, we have selected a total sample size of 28 subjects. According to some experiments that has been done with G*Power (Faul 2013, Statistics_Solutions 2013), Power analysis for a MANOVA with two levels and two dependent variables, using an alpha of 0.05, a power of 0.80, and a large effect size (f = 0.40) requires a sample size of 28.

Having equal cell sizes as described in Table 12, will help making the statistical tests less sensitive to violations of the assumptions, especially the test for homogeneity of variance of the dependent variable. Box's M tests for equality of the covariance matrices (Hair, Black et al. 2010). As shown in table 13, which shows the test for the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups, we have a significant value of 0.325, which is higher than 0.001, which means that we met the assumption that the variance of the dependent variable homogenies across groups.

Table 13. Box's Test of Equality of Covariance Matrices

| | |
|---|---|
| **Box's M** | 3.791 |
| **F** | 1.158 |
| **df1** | 3 |
| **df2** | 121680.000 |
| **Significance** | .324 |

***Outliers Detection***

The second assumption has to do with outlier detection. To proceed with MANOVA we need to make sure that our data is free of outliers A simple approach that identifies extreme points for each group is the use of box plots (Hair, Black et al. 2010). Another well-known approach to detect outlier in multivariate analysis is to use the Mahalanobis' distance. Mahalanobis distance is “the distance from the case to the centroid of all cases for the predictor variables. A large distance indicates an observation that is an outlier in the space denned by the predictors” (Stevens 1984). The Mahalanobis distance is very sensitive to the presence of outliers, where a single extreme observations, or groups of observations, can have a noticeable effect of the Mahalanobis' distance measure (Filzmoser, Garrett et al. 2005). Table 14 shows the critical values (upper bounds) for the Mahalanobis' distance across different number of dependent variables (Penny 1996).

Results from the regression analysis and the examination of the Mahalanobis' distance value, we can see that we have no outliers in our dataset, as the maximum Mahalanobis' distance equals to 6.164, which is less than the critical value based on table 14, more specifically, less than 13.82 (wikiversity 2011).

Table 14. Critical Values (Upper Bounds) for the Mahalanobis' distance.

| | Bounds for the following values of n | | | | |
|---|---|---|---|---|---|
| **P** | **5** | **10** | **20** | **50** | **100** |
| **2** | 3.20 | 7.92 | 13.80 | 21.04 | 23.22 |
| **3** | 3.20 | 7.98 | 15.08 | 21.05 | 28.42 |
| **4** | | 8.05 | | | |
| **6** | | 8.10 | | | |
| **8** | | 8.10 | | | |
| **10** | | | 17.70 | | |
| **18** | | | 18.05 | | |

Also, according to boxplots shown in figure 6, we do not have any outlier for both dependent variables.

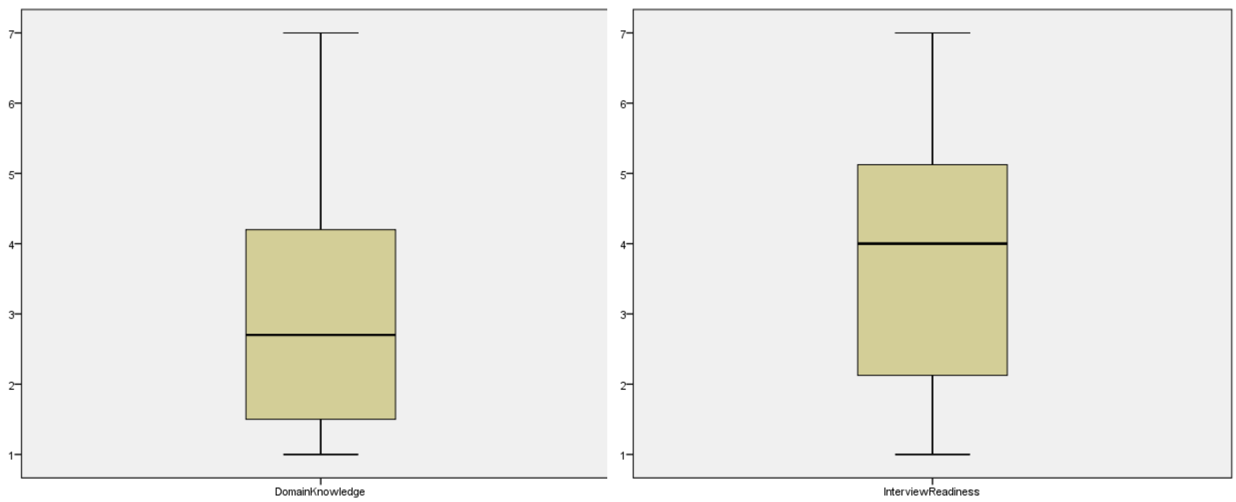


Figure 6. Boxplot for Outlier Detection: Domain Knowledge and Interview Readiness

***Multivariate Linearity***

Next we test for the presence of linear relationship among the dependent variables, specifically, examining the data and assessing the presence of any nonlinear relationships. If these exist, then the decision can be made whether they need to be incorporated into the dependent variable set, at the expense of increased complexity but greater representativeness (Hair, Black et al. 2010). Scatter plot can be used to test for linearity using the elliptical pattern, where linearity hold if and only if there is no deviation from an elliptical pattern (Rothkopf, Arrow et al. 1997) that goes from bottom left to top right (Arthur 2002).

As shown in figure 7, the scatter plot presents a general pattern, with no square like plots, which match the elliptical pattern criteria, i.e., the data meet the assumption of linear relationship.

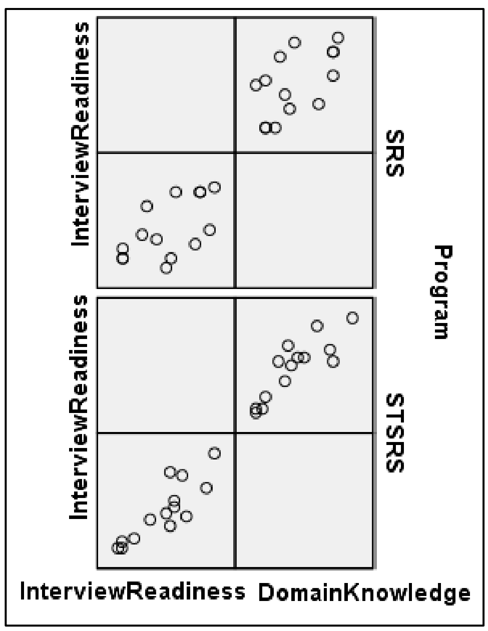


Figure 7. Scatter plot: Domain Knowledge and Interview Readiness

***Multivariate Normality***

Another assumption for MANOVA is the multivariate normality. A multivariate normal distribution "assumes that the joint effect of two variables is normally distributed. Even though this assumption underlies most multivariate techniques, no direct test is available for multivariate normality. Therefore, most researchers test for univariate normality of each variable" (Hair, Black et al. 2010). The two most common are the Shapiro-Wilks test and a modification of the Kolmogorov-Smirnov test. Each calculates the level of significance for the differences from a normal distribution (Dufour, Farhat et al. 1998, Mendes and Pala 2003, Hair, Black et al. 2010).

Table 15. Shapiro-Wilks Test of Normality

| | Shapiro-Wilk | | |
|---|---|---|---|
| | **Statistic** | **df** | **Sig.** |
| **Domain Knowledge** | .934 | 28 | .078 |
| **Interview Readiness** | .943 | 28 | .128 |

For this test we decided to use the Shapiro-Wilk (Mendes and Pala 2003). According to table 15, we arrive at p-value of 0.078 for domain knowledge and p-value of 0.128 for interview readiness. Since p-value of $0.078 > .05 = \alpha$, and p-value of $0.128 > .05 = \alpha$, we retain the null hypothesis that the data are normally distributed.

***Multicollinearity***

In MANOVA, the researcher must also consider the effects of multi-collinearity of the dependent variables on the power of the statistical tests. The simplest and most obvious means of identifying collinearity is an examination of the correlation matrix for the independent variables. "The presence of high correlations (generally .90 and higher) is the indication of substantial collinearity" (Hair, Black et al. 2010).

Table 16 shows the Pearson correlation results among dependent variables, domain knowledge and interview readiness. The correlation between the two variables equal to 0.747 which is less than 0.90, which means that we have no Multi-collinearity issues within the data, and that we can proceed with the MANOVA test.

Table 16. Pearson Correlation

| | | Interview Readiness | Domain Knowledge |
|---|---|---|---|
| **Interview Readiness** | **Pearson Correlation** | 1 | .747 |
| | **Sig. (2-tailed)** | | .000 |
| | **N** | 28 | 28 |
| **Domain Knowledge** | **Pearson Correlation** | .747 | 1 |
| | **Sig. (2-tailed)** | .000 | |
| | **N** | 28 | 28 |

***Hypothesis Testing***

Since all the assumptions hold for the Pretest data, then we can proceed with MANOVA test. The objective of this test is to check whether the two groups are equivalent before they are exposed to any treatment. So, we hypothesis the followings:

*$H1_0$: There is no difference between the Treatment group and the Control group* $(\mu t = \mu c)$

*$H1_a$ : There is a significant difference between the Treatment group and the Control group* $(\mu t \neq \mu c)$

And our objective here is to accept the null hypothesis in order to support our assumption.

Table 17 shows the between-subjects factors statistics. As mentioned before, we have two groups, a treatment group (STSRS) and a control group (SRS). Each group has a total of 14 subjects.

Table 17. Between-Subjects Factors

| | | Value Label | N |
|---|---|---|---|
| **Program** | 0 | SRS | 14 |
| | 1 | STSRS | 14 |

Table 18 shows some descriptive statistics among dependent variables across different group. As shown in the table we have comparable means for domain knowledge across the treatment group (3.37) and the control group (2.63). Also, we have almost similar means for interview readiness across the treatment group (3.57) and the control group (3.84).

Table 18. Descriptive Statistics

| | Program | Mean | Std. Deviation | N |
|---|---|---|---|---|
| **Domain Knowledge** | **SRS** | 2.63 | 1.240 | 14 |
| | **STSRS** | 3.37 | 1.886 | 14 |
| | **Total** | 3.00 | 1.611 | 28 |
| **Interview Readiness** | **SRS** | 3.57 | 1.708 | 14 |
| | **STSRS** | 3.84 | 1.905 | 14 |
| | **Total** | 3.71 | 1.781 | 28 |

Table 19. Tests of Between-Subjects Effects

| Dependent Variable | Mean Square | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power |
|---|---|---|---|---|---|
| **Domain Knowledge** | 3.863 | .229 | .055 | 1.517 | .220 |
| **Interview Readiness** | .502 | .699 | .006 | .153 | .066 |

Interpreting the tests of between-subjects' effects from table 19, we can see that there is no statistical significant difference across the level of independent variable on each of the dependent variables, where the significance value for domain knowledge is 0.229 and the significant value for interview readiness is 0.699.

Interpreting the Levene's test (Hair, Black et al. 2010) of equality of error variances from table 20, we can see that we have non-significant results for both domain knowledge and interview readiness, which means that we have no problems with the homogeneity of variance across outcome variable separately.

The four most commonly used multivariate tests (Pillai's criterion, Wi1ks' lambda, Hotelling's T2 and Roy's greatest characteristic root) (Hair, Black et al. 2010). Table 21 shows the multivariate tests results.

Based on the value of the Wi1ks' lambda as well as other tests, we can see from the table that there is no statistical significant difference across the level of independent variable on the linear combination of the dependent variables. In our case, Wi1ks' lambda has a non-significance value of (0.366), which is higher than alpha = .05, and that provide sufficed evidence to accept the null hypotheses. *$H1_0$: There is no difference between the Treatment group and the Control group ($\mu t = \mu c$)*, is supported and that the two groups are statically equivalent before they are exposed to any treatments.

Table 20. Levene's Test of Equality of Error Variances

| | F | df1 | df2 | Sig. |
|---|---|---|---|---|
| **Domain Knowledge** | 1.958 | 1 | 26 | .174 |
| **Interview Readiness** | .075 | 1 | 26 | .786 |

Table 21. Multivariate Tests [a]

| Effect | | Value | F | Hypothesis df | Error df | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Powerc |
|---|---|---|---|---|---|---|---|---|---|
| **Intercept** | **Pillai's Trace** | .828 | 60.009b | 2.000 | 25.000 | .000 | .828 | 120.018 | 1.000 |
| | **Wilks' Lambda** | .172 | 60.009b | 2.000 | 25.000 | .000 | .828 | 120.018 | 1.000 |
| | **Hotelling's Trace** | 4.801 | 60.009b | 2.000 | 25.000 | .000 | .828 | 120.018 | 1.000 |
| | **Roy's Largest Root** | 4.801 | 60.009b | 2.000 | 25.000 | .000 | .828 | 120.018 | 1.000 |
| **Program** | **Pillai's Trace** | .077 | 1.047b | 2.000 | 25.000 | .366 | .077 | 2.094 | .212 |
| | **Wilks' Lambda** | .923 | 1.047b | 2.000 | 25.000 | .366 | .077 | 2.094 | .212 |
| | **Hotelling's Trace** | .084 | 1.047b | 2.000 | 25.000 | .366 | .077 | 2.094 | .212 |
| | **Roy's Largest Root** | .084 | 1.047b | 2.000 | 25.000 | .366 | .077 | 2.094 | .212 |

c. Computed using alpha = .05

More we get to the contrast as shown in table 22, where looking at the significant values for both dependent variables across different groups, we can see that the values are not significant with (0.229) and (0.699) for domain knowledge and Interview readiness respectively, which both provide support to accept our null hypothesis where there is no significant difference between the two groups before any of the exposed to any treatments.

Table 22. Contrast Results (K Matrix)

| | | | Dependent Variable | |
|---|---|---|---|---|
| **Program** | **Simple Contrast** | | **Domain Knowledge** | **Interview Readiness** |
| **Level 1 vs. Level 2** | **Contrast Estimate** | | -.743 | -.268 |
| | **Hypothesized Value** | | 0 | 0 |
| | **Difference (Estimate - Hypothesized)** | | -.743 | -.268 |
| | **Std. Error** | | .603 | .684 |
| | **Sig.** | | .229 | .699 |
| | **95% Confidence Interval for Difference** | **Lower Bound** | -1.983 | -1.674 |
| | | **Upper Bound** | .497 | 1.138 |

***MANOVA Assumptions (Post-test) and Hypothesis Testing***

Similar to pretest, before proceeding with hypothesis testing using MANOVA, we have conducted different tests to make sure that the main assumptions behind MANOVA hold. These tests for assumptions are described as follow:

***Homogeneity of Variance***

This assumption holds as described before in the MANOVA Assumptions (Post-test) section. As shown in table 23, which shows the test for the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups. As shown in the table, we have a significant value of 0.158, which is higher than 0.001, which means that we met the assumption that the variance of the dependent variable is homogenies across groups.

Table 23. Box's Test of Equality of Covariance Matrices

| | |
|---|---|
| **Box's M** | 5.665 |
| **F** | 1.731 |
| **df1** | 3 |
| **df2** | 121680.000 |
| **Significance** | .158 |

***Outliers Detection***

The second assumption has to do with outlier detection. To proceed with MANOVA we need to make sure that our data is free of outliers. A simple approach that identifies extreme points for each group is the use of box plots. Another well-known approach to detect outlier in multivariate analysis is to use the Mahalanobis' distance as described before. Results from the regression analysis of the data are shown in table 13. Looking at the Mahalanobis' distance value, we can see that we have no outliers in our dataset, as the maximum Mahalanobis' distance equals to 11.446, which is less than the critical value based on table 12, more specifically, less than 13.82 (wikiversity 2011).

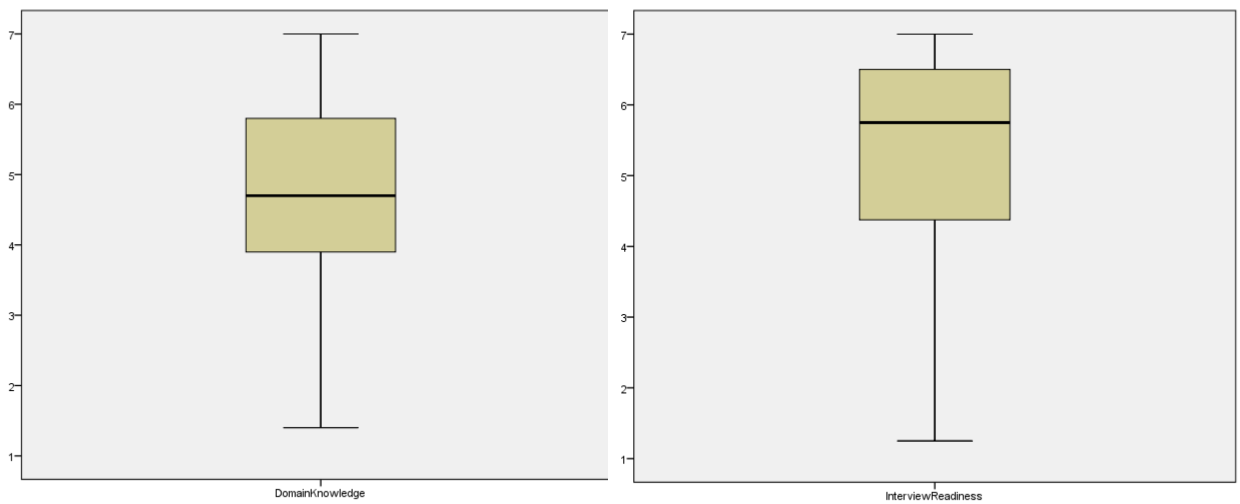


Figure 8. Boxplot for Outlier Detection: Domain Knowledge and Interview Readiness

Also, according to boxplots shown in figure 8, we do not have any outlier for both dependent variables.

***Multivariate Linearity***

Next we test for the presence of linear relationship among the dependent variables. Researcher is encouraged to examine the data and assess the presence of any nonlinear relationships. If these exist, then the decision can be made whether they need to be incorporated into the dependent variable set, at the expense of increased complexity but greater representativeness (Hair, Black et al. 2010). Scatter plot can be used to test for linearity using the elliptical pattern, where linearity hold if and only if there is no deviation from an elliptical pattern (Rothkopf, Arrow et al. 1997) that goes from bottom left to top right (Arthur 2002).

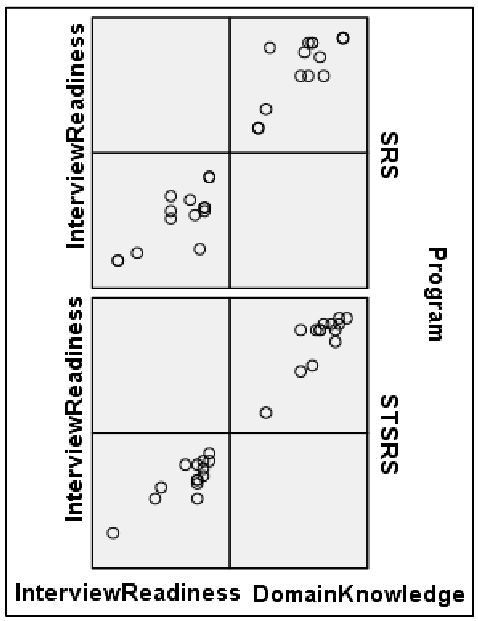


Figure 9. Scatter plot: Domain Knowledge and Interview Readiness

What we are looking at from figure 9 is the elliptical pattern that moves from bottom left to the top right. From the scatter plot we have a general pattern, with no square like plots, which match the elliptical pattern criteria, which means that the data meet the assumption of linear relationship.

***Multivariate Normality***

Another assumption for MANOVA is the multivariate normality. A multivariate normal distribution "assumes that the joint effect of two variables is normally distributed. Even though this assumption underlies most multivariate techniques, no direct test is available for multivariate normality. Therefore, most researchers test for univariate normality of each variable" (Hair, Black et al. 2010). The two most common are the Shapiro-Wilks test and a modification of the Kolmogorov-Smirnov test. Each calculates the level of significance for the differences from a normal distribution (Dufour, Farhat et al. 1998, Mendes and Pala 2003, Hair, Black et al. 2010).

Table 24. Shapiro-Wilks Test of Normality

| | Shapiro-Wilk | | |
|---|---|---|---|
| | **Statistic** | **df** | **Sig.** |
| **Domain Knowledge** | .930 | 28 | .061 |
| **Interview Readiness** | .850 | 28 | .001 |

For this test we decided to use the Shapiro-Wilk (Mendes and Pala 2003). According to table 24, we arrive at p-value of 0.061 for domain knowledge and p-value of 0.001 for interview readiness. Since p-value of $0.061 > .05 = \alpha$, and p-value of $0.001 < .05 = \alpha$, we retain the null hypothesis that the data are normally distributed for domain knowledge, but not for interview readiness. Fortunately, "a violation of this assumption has minimal impact if the groups are of approximately equal size" (Largest group size / Smallest group size < 1.5). (Hair, Black et al. 2010).

## ***Multi-collinearity***

In MANOVA, the researcher must also consider the effects of multi-collinearity of the dependent variables on the power of the statistical tests. The simplest and most obvious means of identifying collinearity is an examination of the correlation matrix for the independent variables. "The presence of high correlations (generally .90 and higher) is the indication of substantial collinearity" (Hair, Black et al. 2010).

Table 25 shows the Pearson correlation results among dependent variables, domain knowledge and interview readiness. The correlation between the two variables equal to 0.854 which is less than 0.90, which means that we have no Multi-collinearity issues within the data, and that we can proceed with the MANOVA test.

Table 25. Pearson Correlation

| | | Interview Readiness | Domain Knowledge |
|---|---|---|---|
| **Interview Readiness** | **Pearson Correlation** | 1 | .854 |
| | **Sig. (2-tailed)** | | .000 |
| | **N** | 28 | 28 |
| **Domain Knowledge** | **Pearson Correlation** | .854 | 1 |
| | **Sig. (2-tailed)** | .000 | |
| | **N** | 28 | 28 |

***Hypothesis Testing***

Since all the assumptions hold for the Pretest data, then we can proceed with MANOVA test. For this test, we argue that access to the ST based system will increases the analyst's domain knowledge more than those who have not, which also will make the analyst feel better prepared for proceeding with users' interviews.

*$H2_0$: There is no difference between the self-reported domain knowledge of analysts who have accesses the ST based systems and those who have not ($\mu t = \mu c$)*

*$H2_a$: There is a significant difference between the self-reported domain knowledge of analysts who have accesses the ST based systems and those who have not ( $\mu t > \mu c$)*

*$H3_0$: There is no difference between the self-reported interview readiness of analysts who have accesses the ST based systems and those who have not ($\mu t = \mu c$)*

*$H3_a$: There is a significant difference between the self-reported interview readiness of analysts who have accesses the ST based systems and those who have not ( $\mu t > \mu c$)*

And our objective here is to reject the null hypothesis in order to support our assumption. Table 26 shows the between-subjects factors statistics. As mentioned before, we have two groups, a treatment group (STSRS) and a control group (SRS). Each group has a total of 14 subjects.

Table 26. Between-Subjects Factors

| | | Value Label | N |
|---|---|---|---|
| **Program** | 0 | SRS | 14 |
| | 1 | STSRS | 14 |

Table 27 shows some descriptive statistics among dependent variables across different group. As shown in the table we have a slightly higher mean for domain knowledge across the treatment group (5.629) than the control group (3.671). Also, a slightly higher mean for Interview readiness across the treatment group (6.107) than the control group (4.411).

Table 27. Descriptive Statistics

| | Program | Mean | Std. Deviation | N |
|---|---|---|---|---|
| **Domain Knowledge** | **SRS** | 3.671 | 1.4835 | 14 |
| | **STSRS** | 5.629 | 1.0979 | 14 |
| | **Total** | 4.650 | 1.6226 | 28 |
| **Interview Readiness** | **SRS** | 4.411 | 1.7058 | 14 |
| | **STSRS** | 6.107 | 1.1211 | 14 |
| | **Total** | 5.259 | 1.6590 | 28 |

The four most commonly used multivariate tests (Pillai's criterion, Wi1ks' lambda, Hotelling's T2 and Roy's greatest characteristic root) (Hair, Black et al. 2010). Table 31 shows the multivariate tests results.

Based on the value of the Wi1ks' lambda as well as other tests, we can see from the table that there is a statistical significant difference across the level of independent variable on the linear combination of the dependent variables. In our case, Wi1ks' lambda has a significance value of (0.003), which is less than alpha = .05, and that provide sufficed evidence to reject the null hypotheses. So, $H2_a$ and $H3_a$ are supported and that the two groups are statically different after they are exposed to any treatments. However, based on these results, we have no idea where that difference is, whether it is on domain knowledge or interview readiness.

Interpreting the tests of between-subjects' effects from table 28, we can also see that there is a statistical significant difference across the level of independent variable on each of the dependent variables, where the significance value for domain knowledge is 0.001 and the significant value for interview readiness is 0.005. This also provide the necessary support for $H2_a$ and *H3a* are and that the two groups are statically different after they are exposed to any treatments. However, based on these results, we have no idea where that difference is, whether it is on domain knowledge or interview readiness.

Table 28. Tests of Between-Subjects Effects

| Dependent Variable | Mean Square | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power |
|---|---|---|---|---|---|
| **Domain Knowledge** | 26.813 | 15.745 | .001 | .377 | 15.745 |
| **Interview Readiness** | 20.145 | 9.670 | .005 | .271 | 9.670 |

Moreover we get to the contrast as shown in table 29, where looking at the significant values for both dependent variables across different groups, we can see that the values are significant with (0.001) and (0.005) for domain knowledge and Interview readiness respectively, which both provide support to reject our null hypothesis $H2_0$ and $H3_0$ and accept $H2_a$ and $H3_a$.

Table 29. Contrast Results (K Matrix)

| Program | Simple Contrast | | Dependent Variable: Domain Knowledge | Dependent Variable: Interview Readiness |
|---|---|---|---|---|
| **Level 1 vs. Level 2** | **Contrast Estimate** | | -1.957 | -1.696 |
| | **Hypothesized Value** | | 0 | 0 |
| | **Difference (Estimate - Hypothesized)** | | -1.957 | -1.696 |
| | **Std. Error** | | .493 | .546 |
| | **Sig.** | | .001 | .005 |
| | **95% Confidence Interval for Difference** | **Lower Bound** | -2.971 | -2.818 |
| | | **Upper Bound** | -.943 | -.575 |

Interpreting the Levene's test (Hair, Black et al. 2010) of equality of error variances from table 30, we can see that we have non-significant results for both domain knowledge and interview readiness, which means that we have no problems with the homogeneity of variance across outcome variable separately.

Table 30. Levene's Test of Equality of Error Variances

| | F | df1 | df2 | Sig. |
|---|---|---|---|---|
| **Domain Knowledge** | 1.958 | 1 | 26 | .174 |
| **Interview Readiness** | .075 | 1 | 26 | .786 |

Table 31. Multivariate Tests

| Effect | | Value | F | Hypothesis df | Error df | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Powerc |
|---|---|---|---|---|---|---|---|---|---|
| **Intercept** | **Pillai's Trace** | .940 | 195.156b | 2.000 | 25.000 | .000 | .940 | 390.312 | 1.000 |
| | **Wilks' Lambda** | .060 | 195.156b | 2.000 | 25.000 | .000 | .940 | 390.312 | 1.000 |
| | **Hotelling's Trace** | 15.612 | 195.156b | 2.000 | 25.000 | .000 | .940 | 390.312 | 1.000 |
| | **Roy's Largest Root** | 15.612 | 195.156b | 2.000 | 25.000 | .000 | .940 | 390.312 | 1.000 |
| **Program** | **Pillai's Trace** | .377 | 7.571b | 2.000 | 25.000 | .003 | .377 | 15.143 | .916 |
| | **Wilks' Lambda** | .623 | 7.571b | 2.000 | 25.000 | .003 | .377 | 15.143 | .916 |
| | **Hotelling's Trace** | .606 | 7.571b | 2.000 | 25.000 | .003 | .377 | 15.143 | .916 |
| | **Roy's Largest Root** | .606 | 7.571b | 2.000 | 25.000 | .003 | .940 | 15.143 | .916 |

c. Computed using alpha = .05

***Questionnaire Quality***

This section examine the questionnaire quality developed by different subjects in different groups. In this perspective, the analyst performance when developing the interview questionnaire was compared for those who have accessed to the ST based system (treatment group) and those who do not have access (control group). In order to assess analysts' performance, we need a judge (someone who is expert in the domain of system analysis and design) in order to assess the quality of the interviews questions. In this context, we argue that access to ST requirement elicitation support system will improve the overall performance of the analysts. The analyst' initial domain knowledge is used as a control variable to account for the variability of the domain knowledge at the start of the study.

*$H4_0$: There is no difference between user interview questionnaire quality of analysts who have accesses the ST based systems and those who have not ($\mu t = \mu c$)*

- *$H4.1_0$: There is no difference between user interview questionnaire breadth of analysts who have accesses the ST based systems and those who have not ($\mu t = \mu c$)*
- *$H4.2_0$: There is no difference between user interview questionnaire depth/ breadth of analysts who have accesses the ST based systems and those who have not ($\mu t = \mu c$)*

*$H4_a$: There is a significant difference between user interview questionnaire quality of analysts who have accesses the ST based systems and those who have not ( $\mu t > \mu c$)*

- *$H4.1_a$: There is a significant difference between user interview questionnaire breadth of analysts who have accesses the ST based systems and those who have not ( $\mu t > \mu c$)*
- *$H4.2_a$: There is a significant difference between user interview questionnaire depth/ breadth of analysts who have accesses the ST based systems and those who have not ( $\mu t > \mu c$)*

Where the quality of the questionnaire developed by the analysts using the ST requirement elicitation support system will be better than those who have not.

***Hypothesis Testing***

Before proceeding with hypothesis testing, we need to make sure that the judge did a good job analyzing the questionnaire. Since we have questions that does not adhere to our interrogatories questioning technique, which involves asking "who," "what," "when," "where," "how," and "why"; questions, then we decided to remove these questions that are mainly yes/no questions that capture only one piece of information at a time, which is considered not effective way to collect requirements. Table 32 shows the number of questions per group with interrogatories questions and all questions.

Table 32. Number of Questions per group

| | **Number of Questions** | |
|---|---|---|
| | **All Questions** | **Interrogatories Questions** |
| **Treatment Group** | 201 | 155 |
| **Control Group** | 168 | 55 |

These numbers obviously show that we have a problem when it comes to writing effective questions, especially foe the control group, where the control group was able to write 55 interrogatories questions out of 168 questions, where most of the questions are yes/no questions that are mainly targeting one piece of information each time. Example questions written by the subjects include"

"*Do you need the application to include trophies and medals to encourage you towards a healthy life*"?

This questions can be rewritten using the interrogatories questioning technique as follow:

"*Using the application, what encourage you towards a healthy life*"?

Another example:

"*Do you wish to receive email or notification on the system daily*"?

This questions can be rewritten using the interrogatories questioning technique as follow:

"*How do you want to receive diabetes related information using the mobile application*"?

One more example:

"*Do you wish the application to include dashboards and graphs to indicate for your glucose measurements*"?

This questions can be rewritten using the interrogatories questioning technique as follow:

"*How do you want to display glucose measures overtime using the mobile application*"?

For each questionnaire the breadth and depth are calculated. Then a mean values are calculated for the breadth and the depth/breadth values for all questionnaires. Such values will be used to do a t-test between the two groups. Results for these measures are shown in table 33.

Table 33. Means and standard deviations for breadth and depth/breadth - Interrogatories Questions

| | **Breadth** | | **Depth/Breadth** | |
|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** |
| **Treatment Group** | 2.64 | 1.15 | 5.08 | 3.54 |
| **Control Group** | 1.14 | 1.10 | 1.99 | 2.82 |

Independent samples test for breadth is shown in table 34. Results from the analysis reveals a statistically significant value of 0.002, which means that there is a difference between the two groups when it comes to the breadth of the questionnaire. This means that *H4.1*$_0$ is rejected and our hypothesis *H4.1*$_a$ is accepted.

Table 34. Independent Samples Test - Breadth

| | | **Levene's** | | **t-test for Equality of Means** | | |
|---|---|---|---|---|---|---|
| | | **F** | **Sig.** | **Sig. (2-tailed)** | **Mean Difference** | **Std. Error Difference** |
| **Breadth** | **Equal variances assumed** | .148 | .704 | .002 | 1.50 | .42535 |
| | **Equal variances not assumed** | | | .002 | .1.50 | .42535 |

Levene's Test for Equality of Variances

Independent samples test for depth/breadth is shown in table 35. Results from the analysis reveals a statistically significant value of 0.017, which means that there is a difference between the two groups when it comes to the depth/breadth of the questionnaire. This means that $H4.2_0$ is rejected and our hypothesis $H4.2_a$ is accepted.

Table 35. Independent Samples Test – Depth/Breadth

| | | **Levene's** | | **t-test for Equality of Means** | | |
|---|---|---|---|---|---|---|
| | | **F** | **Sig.** | **Sig. (2-tailed)** | **Mean Difference** | **Std. Error Difference** |
| **Depth/Breadth** | **Equal variances assumed** | .1.662 | .209 | .017 | 3.09524 | 1.20995 |
| | **Equal variances not assumed** | | | .017 | 3.09524 | 1. 20995 |

Levene's Test for Equality of Variances

Overall, the test for both breadth and depth/breadth does support our assumption. In other words, the tests accept our hypothesis H41 and rejects the null hypothesis $H4_0$.

# CHAPTER 5

# CONCLUSIONS

**Summary and Findings:**

Systems needs are determined through a requirements elicitation process. Traditional methods of elicitations failed because these methods focus only on the technical aspects and constraints of the systems. The success of information system development involves the identification of the social, organizational and technical features of the systems, which in turn results in a more acceptable system by users. For the purpose of this work, we focused on interviews as a method of requirements elicitation. Interviews, whether they are structured, semi-structured, or un-structured, are considered one of the most effective requirements elicitation techniques.

We followed design science research to propose a new process model that can be used to develop a ST based system to help analysts in the requirements analysis phase for building systems that account for the intrinsic and interrelated features of a ST system. More specifically, we investigated how can the socio-technical model enhances analysts' understanding of the problems and help them conduct more effective users' interviews for eliciting more accurate and comprehensive requirements.

We illustrated the application of the prototype in the domain of self-care, e.g., diabetes self-management applications. The proposed process model and ST based system has been tested for its effectiveness in improving analysts' domain knowledge, readiness, and preparations for the requirements analysis phase. A two group, randomized experimental design has been followed. Hypothesis has been developed to test for domain knowledge, interview readiness, and questionnaire quality. An instrument is developed based on existing literature to collect the necessary data. The subjects in the user study are divided into two different groups, a treatment and control group. The treatment groups will have access to the ST based requirement elicitation support system, a modified SRS template, and a hypothetical system description, where the control group will have access to a modified SRS template, and a hypothetical system description in developing the requirement elicitation questionnaire. In this context, random sampling and random assignment are the key to make sure that any differences in the posttest results is related to the treatment and nothing else. The Multivariate analysis of variance (MANOVA) is used to test the hypotheses.

The subjects' performance is modeled from two perspectives. The first perspective is to determine how the analysts feel about their understanding of the domain knowledge and how well they are prepared for the requirements analysis interviews (self-assessment perspective). The second perspective is the analysts' relative performance. In this perspective, the analyst performance when developing the interview questionnaire was compared for the treatment group and the control group.

The proposed process model tries to address limitations with traditional methods of elicitations, namely the focus on the technical aspects and constraints of the systems. The proposed process model is mainly based on the socio-technical systems theory, where the socio-technical model helps identifying the social, organizational and technical features of the systems, which in turn results has it effect on the overall performance of the analysts, whether when it comes to domain knowledge, their interview readiness, or the quality of the questionnaire.

The proposed socio-technical process model addresses problems with what questions to ask. Interviews, whether they are structured, semi-structured, or un-structured, are considered one of the most effective requirements elicitation techniques. However, the interview process involves developing a set of questions, and without proper attention to these questions, the system analysts are likely to 'short-cut' the requirements elicitation process, which in turn affects the completeness and accuracy of the elicited requirements. Despite the fact that it is not easy to define "completeness" with respect to interview questionnaire, the socio-technical process model has proved to be more effective than traditional methods when it comes to the number of questions developed as part of the questionnaire. The socio-technical model helped the analysts by providing with more guidance about the interviews contents or questions, and the kind of questions or inquiry that is most effective.

In addition, our finding provides additional support when it comes to analysts' experience, where analysts' experience does not appear to be a relevant factor when using interviews as an elicitation technique. The control and treatment groups have both similar number of subjects when it comes to experience or no experience (almost 50%:50%) with systems analysis and design as well as software engineering, and our results showed those who are exposed to the socio-technical process model appears to be more effective than those who have not.

The proposed socio-technical process model can be used regardless of the level of the experiences of the analysts, where our groups are comparable when it comes to experience, and results showed that those who are exposed to the socio-technical model performed better than those who have not. As a result, analysts experience does not appear to be a relevant factor, where careful preparation of interviews has a much more marked effect than analyst experience.

The socio-technical process model helped also improving analysts' domain knowledge. This is also support existing findings from the literature where analysts who are familiar with the domain, can more easily prepare focused questions for an interview as opposed to other traditional analysts who focus on the solution not the problem, and reply on only those techniques they are familiar with for all situations. The reason why the socio-technical model improves analysts' domain knowledge is contributed to the analysts' ability to explore technical aspects of the problem domain as well as political, organizational, and social aspects related to the system by using the socio-technical process model.

Finally, overall, quality of the questionnaire found to be much better for those analysts who are exposed to the socio-technical model than those who have not. Despite the fact that measuring quality is hard at this level, we have deployed the concepts of depth and breadth to judge the overall quality. Finding from the analysis of depth and breadth, where the researcher excluded the yes/no questions showed that the overall quality has improved for the treatment group.

## Contribution

The contribution of this work can be described along three dimensions: empirical, theoretical, and practical. A major empirical contribution of this work is to show how such process model can affect analysts' understanding and learning. The process model has been used to enhance analyst' domain knowledge as well as their interview readiness. Results from hypothesis testing and data analysis showed that those who are exposed to the ST based knowledge base reported enhanced domain knowledge as well as interview readiness more than those who have not.

The theoretical contribution is a new way to improve analysts' domain knowledge and preparation for developing interview questionnaire. In the ST System literature, there is a lack of a midrange theoretical model for ST systems analysis and design. The studies we have are very abstract and do not provide any artifact, specific steps, or process for the purpose of practicing STS analysis and design. To do so, a new ST process model based on the notion of ST model of information systems is developed.

Finally, the practical contribution is an attempt to show that such theoretical ideas can be usefully applied to show that such ST process model can results in a change in analysts' domain knowledge and understanding of problem domain.

**Limitations and Future Work**

As with most research, this study has limitations that can be noted. The complete potential of the proposed ST process model has not been experienced by the subjects in the treatment group. Despite the fact the proposed ST process model has proven its usefulness, the subjects were only exposed to a very limited information about the domain. The reason behind that is the time required for the analysts to experience the ST based knowledge base as with the current settings subjects has spent an average of one hour to go through the complete tasks including the exploring the domain knowledge, the pre and post surveys as well as developing the questionnaire.

The results concluded from this study might not be generalizable. The study was focused on the domain of self-care, more specifically, the diabetes mobile application, there is a need to replicate the study in different problem domain and see if we can obtain similar results to what we have in this study.

Not all of the subjects involved in the study are practicing analysts who are involved in systems analysis and design processes. Some of the students have the knowledge of systems analysis and design without practicing systems analysis and design as professionals. Accordingly, there is a need to explore the effect of the proposed ST process model on systems analysts who are involved in the process of developing systems.

Finally, gender differences appear to be a relevant factor in different research studies. Despite the fact the subjects involved in the study are different in terms of number of males and females, where the treatment group has a total of 11 males and 3 males, and the control group has a total of 14 males, we believe that the way the sample selected and distributed among groups as well as the pre-test helped avoiding such gender differences issues, where such techniques help control for other major explanatory factors.

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