Behavioral software engineering: A definition and systematic literature review

Per Lenberg [a,*], Robert Feldt [b], Lars Göran Wallgren [c]

[a] *Division of Software Engineering, Chalmers University, SE-412 96 Gothenburg, Sweden*
[b] *Department of Software Engineering, Blekinge Institute of Technology, Karlskrona, Sweden*
[c] *Department of Psychology, Gothenburg University, Gothenburg, Sweden*

A R T I C L E   I N F O

A B S T R A C T

Throughout the history of software engineering, the human aspects have repeatedly been recognized as important. Even though research that investigates them has been growing in the past decade, these aspects should be more generally considered.

The main objective of this study is to clarify the research area concerned with human aspects of software engineering and to create a common platform for future research. In order to meet the objective, we propose a definition of the research area behavioral software engineering (BSE) and present results from a systematic literature review based on the definition.

The result indicates that there are knowledge gaps in the research area of behavioral software engineering and that earlier research has been focused on a few concepts, which have been applied to a limited number of software engineering areas. The individual studies have typically had a narrow perspective focusing on few concepts from a single unit of analysis. Further, the research has rarely been conducted in collaboration by researchers from both software engineering and social science.

Altogether, this review can help put a broader set of human aspects higher on the agenda for future software engineering research and practice.

1. Introduction

Early in the development of the software engineering (SE) field it was recognized that one also had to consider the humans involved in software development (Weinberg, 1971). However, much of the research and practice in subsequent years focused mainly on technological or process-related factors while research that considered organizational, social or psychological factors was rare (Perry et al., 1994). Even if the introduction and focus on agile methods in the last 10–15 years has, yet again, highlighted the importance of people, teams and their communication and collaboration (Cockburn, 2006; Highsmith, 2002; Pikkarainen et al., 2008) these issues can still not be considered to be in the SE mainstream.

As an indication of this negative bias, we searched the ISI Web of Science and found that while 70% of papers in SE or software development also list a technology- or process-related topic less than 5% list a 'soft' or human-related topic.[1] Interestingly, even though this

indicates there is still at least 10 times more technology- and process-focused research being carried out, our estimation shows that the percentage of research in ISI Web of Science that also considers softer, human aspects has increased from around 2% in 1993 to over 7% in 2013, more than a three-fold increase. Part of this increase can no doubt be attributed to an increasing number of workshops and outlets for this type of research (de Souza et al., 2009; Sharp et al., 2014).

While this growth is encouraging we argue that these concerns must be more generally considered in SE research. We and others have argued (Feldt et al., 2008; Fernando Capretz, 2014) that psychometric measurements should be taken into account in any SE research and there has been systematic literature reviews on other related aspects such as motivation (Beecham et al., 2008; Hall et al., 2009; Sharp et al., 2009), personality (Cruz et al., 2011) and organizational culture (Leidner and Kayworth, 2006). These are a key aspect when describing the context for SE research, which are so crucial to

---

* Corresponding author. Tel.: +46 734379815.
E-mail addresses: perle@chalmers.se (P. Lenberg), robert.feldt@bth.se (R. Feldt), larsgoran.wallgren@psy.gu.se (L.G. Wallgren).

[1] We searched the ISI Web of Science on June 25th 2014 first for papers listing topics that match 'software engineering' or 'software development' and then checking how

large a percentage of those that also list a topic among either a technology or process-related topic ('design', 'architecture', 'requirements', 'programming', 'testing', or 'verification') versus the ones that also list a 'soft' or human-related aspect ('social*', 'human factors', 'psychol*' or 'personality'). Even though this gives only a very coarse-grained indication we argue that it can at least act as a rough estimate of the relative amount of research done of each type.

building generally useful theories and results (Petersen and Wohlin, 2009). If we miss these aspects, we risk producing results that do not uncover key factors in determining the success or failure of software projects. As an example, the human reluctance to change (Oreg, 2003) might be more important to consider in a software process improvement effort than exactly which process change is made or which tool is introduced. However, most research on software process improvement focus on the actual change rather than the people that will have to change their behavior (Unterkalmsteiner et al., 2012).

The main objective of this study is to clarify the research area concerned with human aspects of software engineering and to create a common platform for future research. In order to meet the objective, we propose a definition of the research area behavioral software engineering (BSE) and present results from a systematic literature review based on the BSE definition.

We argue that it is important to clearly define a specific area concerned with more realistic notions of human nature in order to better understand and improve software development processes and practices. In addition to the scientific value of having a clearly defined area of discourse we also argue that the definition is needed for political reasons. We need a definition and key concepts in arguments externally, to funding agencies and the society at large, as well as internally, to other SE researchers more focused on technical or process/method aspects of SE work. An inspiration is behavioral economics (see Section 2) and the relative importance that this sub-field of economics has gained in a relatively short time span.

Furthermore, the systematic literature review shall identify what have been studied, but also examine how the studies have been conducted. It aims to identify gaps in current research, identify trends and point to directions for future research. Thus, the primary focus of the SLR is the BSE research area as a whole, not the individual BSE concepts.

In the next section, we give further background and briefly present related research areas. After that, we present the methods used to define BSE and to conduct the systematic literature review. Next, the results are presented and discussed. Finally, the paper is concluded.

2. Background

More realistic understanding of the people involved in software development activities must be based on multiple scientific disciplines; software development is a very rich set of activities with connections to many existing fields. Over time, it is likely that many subfields of both psychology, social as well as organizational science will have to be considered for a fuller understanding of software development processes and practices.

In the following section we briefly describe the areas of research that we have deemed most relevant and that have affected our proposed definition and model of behavioral software engineering (BSE). These main areas are work and organization psychology, psychology in programming and behavioral economics. Below we also review how these topics have been described in different conferences and sub-areas within software engineering. Finally, we briefly describe software literature reviews in software engineering.

2.1. Related research

2.1.1. Work and organizational psychology

Psychology is defined as the scientific study of thinking, emotions and behavior. Naturally, organizational psychology[2] is the application of psychology in the workplace, i.e. concerned with 'behavior in the workplace' (Muchinsky, 1997).

---

[2] Also sometimes referred to as industrial and organizational psychology, occupational psychology, or work psychology.

Work and organizational psychology has only been in existence for about the last century. The question of what is significant for an individual's well-being and job satisfaction has been one of the most important research areas in organizational psychology since the 1920s. In the 1920s the research concentrated on physical work conditions such as lighting, ventilation and noise level and the beginning of the 1930s to the beginning of the 1940s, the interest in the social aspects of the work environment increased. In these years the human relations movement began, with Elton Mayo (1946) as one of its main spokesmen. Today work and organizational psychology raises important questions about how to manage effectively in organizations in particularly with the increasing number of knowledge workers whose commitment is critical to organizational success.

Knowledge workers such as IT consultants and software engineers live at the 'edge of change' such as new technologies and methods and the job involve a great deal of collaboration. Thus, this occupation has both a clear connection to other occupations that have been well studied within organizational psychology as well as at least a partly different context with unique aspects. It is important to study this occupation from the main perspectives of individual, group and organization.

2.1.2. Psychology of programming

According to Sajaniemi (2008), psychology of programming (PoP) is an interdisciplinary science that dates back to the late 1970s. The aim of PoP, which covers research in (1) computer programmers' cognition, (2) tools and methods for programming related activities and (3) programming education was originally to make the programmers work more efficiently and to produce better software.

The Psychology of Programming Interest Group (PPIG) was established in the late 1980s (Sajaniemi, 2008). The idea was to bring together researchers with a common interest in psychological aspects of programming but also to cover computational aspects of psychology. PPIG includes researchers from different communities such as cognitive science, psychology, software engineering, computer science etc. (Kutar, 2013).

Even though The Psychology of Programming Interest Group (PPIG) defines the term programming quite broadly to include any aspects of software development the annual workshop series the group hosts mostly emphasize the individual perspective of programming. The research methods discussed and used in PPIG most often have been adopted from cognitive psychology (Sajaniemi, 2008).

2.1.3. Behavioral economics

Behavioral economics (BE) is an interdisciplinary science which aims to establish descriptively accurate findings about human cognitive ability and social interaction with implications on economic behaviors and processes. It uses models and knowledge from several neighboring sciences, and the most influential neighboring science has been psychology (Rabin, 2002). Some scientists argue that psychological economics is a separate strand of behavioral economics which borrows solely from psychology, especially cognitive psychology (Tomer, 2007). Others, single out behavioral finance defined as the area that argues that some financial phenomena can be better understood using models in which some agents are not fully rational' (Barberis and Thaler, 2003).

Nowadays, behavioral economics is a prosperous scientific field with its own conferences and journals. It has had a broad effect on the scientific thinking in the area of economics. Daniel Kahneman received the Nobel prize in Economics in 2002 for his foundational work with Amos Tversky and gave his Nobel lecture on the 'Bounded maps of rationality: Psychology for behavioral economics' (Kahneman, 2003).

The state of affairs in SE shares similarities with the state of affairs in the field of economics before the more widespread acceptance