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The Role of Empirical Studies in Process Improvement

L. M. OTT

Department of Computer Science, Michigan Technological University, USA

A. KINNULA

Nokia Mobile Phones, Ltd. Finland

C. SEAMAN

Information Systems Department, University of Maryland, USA

C. WOHLIN

Department of Communication Systems, Lund University, Sweden

Abstract. Empirical studies can play a multitude of roles in what is loosely called process improvement. In this paper we examine what is meant in the software industry by process improvement and how we can and should be able to use empirical studies to improve software processes. This paper evolved from discussions at the Empirical Studies in Software Development and Evolution Workshop at ICSE99.

Introduction

Concerns related to process improvement have been a part of the software engineering culture for over three decades. Although the terminology hasn't always been consistent, issues such as how to lower development cost and increase the reliability of software and the productivity of programmers as well as numerous other issues have been mentioned frequently over this period. Nearly all discussion of these issues either implicitly or explicitly indicates a need for improvements in the software processes that are used. How should these processes be changed and on what basis should these decisions be made? Empirical studies are one suggestion given as a mechanism to aid in answering these questions in what is assumed to be a more scientific fashion. In this paper we examine the role of empirical studies in process improvement and in a broader view, in process understanding.

Process Improvement, Process Engineering, Process Understanding

An appropriate place to begin this discussion on process improvement is by recalling that process improvement is just one component of the broader discipline of process engineering. Process engineering includes process deployment, process maintenance, and process evolution. Process improvement is one aspect of process evolution. Although software development has now been taking place for over 50 years, process engineering is still a very young field. As such, it is necessary to acknowledge the current limitations of the available foundation for process engineering and hence, process improvement.

One indication of the immaturity of the field is perhaps the overemphasis on process improvement without sufficient emphasis on process understanding. The term process improvement is typically used when focusing on a given process in a given context and when attempting to identify ways to change that particular process in order to achieve some goal. Usually this goal is an improvement either in the actual process or the product resulting from the process. For instance, one might consider adding formal reviews to the process used in a particular organisation because of a belief that this change will increase the quality of the software products produced by that organisation.

Process improvement is what can be most easily focused on in any given context. Given that a group/organisation/company is using a particular process, process improvement focuses on what should be changed to get the desired improvements. This form of process improvement nearly always has a relatively short-term focus. There is typically, however, an unstated assumption that long-term gains in the given environment will be the result of the accumulative short-term gains. Because of industry's need to meet deadlines to ensure marketability of products and profitability, improvements tend to be non-risky and hence small.

What is critical in the long-term is process understanding. Process understanding is focused on developing a scientific foundation for process engineering. Given such an understanding, it should be possible to deploy a process that is best suited to the application and environment and one that is more amenable to process improvement in the long run. It is through process understanding that we are likely to have the revolutionary changes that will result in truly significant process improvement.

Empirical studies aimed at process improvement may not be sufficient to achieve true process understanding. By their nature, these studies are done in a context and certain assumptions in that context often are not open to study. In contrast empirical studies that are designed to enhance process understanding are designed to be more fundamental in nature ensuring for instance that our assumptions about the process are indeed true. Thus, these studies may not lead to immediately applicable process improvement results. True process understanding will require the accumulation of numerous long-term empirical studies from which an appropriate model may be built. This type of research program is not conducive to being carried out in a production environment. But because of its fundamental nature, this research is quite suitable as a university research program. However, because the research on processes can not be totally isolated from practice, co-operation between industry and universities is likely a necessity.

Unlike empirical studies in an immature discipline such as process engineering, in mature disciplines a new study generally rests on the foundation built from earlier studies. When considering process improvement, it is almost as if any given study is designed to examine a random point in space. The relationship between one study and other studies and findings are unclear. The importance of a new finding is uncertain and the potential of a study to contribute to our understanding is often unknown. Without first focusing on developing a foundation and a way to determine the relationship between studies, we may unknowingly be in a situation where our emphasis and energy is misplaced. One might consider an analogy with an attempt to improve the efficiency of office workers. For instance, one might attempt to study the effects of wall colours in the office to improve the productivity

of the employees when in fact a much more fundamental building problem is resulting in minimal air circulation. This lack of air circulation could be causing a very stuffy and unhealthy environment resulting in frequent employee illness and hence a very low level of productivity that is unlikely to be affected by any possible improvement in the colour scheme. Similarly when examining software process, if we do not have a sufficient foundation that allows the identification of the major issues, much effort might be put into studying effects that will have at most a negligible consequence if implemented.

Studies Aimed at Process Improvement

In spite of our argument for studies aimed at process understanding, it is clear that in the immediate future much can be gained from well-planned studies aimed at process improvement. Depending on the study and the environment, these gains will often be primarily aimed at the environment in which the study was conducted. However, certain studies may also lead to establishing the foundation for process understanding. Following are some issues to be considered when planning an empirical study for process improvement.

For results from a study to be meaningful and eventually transferable, sufficient context information is needed. This context information helps to determine the applicability of the results and the similarities between the studied environment and another environment where the results might be applied. Knowing where and how to deploy a new process or a modification is obviously of importance.

Content information will also allow others conducting similar empirical studies to relate their results. If similar results are obtained in multiple contexts, the results might be more fundamental. If, however, different results are obtained in another environment, an awareness of the context might lead to an understanding or at least a hypothesis of confounding factors. This will help to identify the fundamental issues and to build a foundation for process understanding. Even in the instances when empirical studies related to software process issues are conducted in a controlled environment, this context information is obviously still appropriate.

A problem that develops because of growth and change in the industry is the lack of process maintenance. Process improvement makes little sense if the underlying process is eroding. High employee acquisition, mergers, company buyouts, and reorganisations can all diminish the process knowledge. Company mergers for instance may result in employee shuffling. Employees from different work cultures can easily dilute existing processes that were in place. Geographic issues can arise. Processes might evolve to now incorporate team members in geographic disperse time zones or from different cultures radically affecting the presumed process. Even a recently completed study may no longer be applicable if the assumed process has evolved since the study.

When Not to Do Empirical Studies as Part of Process Improvement

In the “real world” it is clearly not always possible to base all decisions to change a process on empirical studies. Minimally the cost would be prohibitive; similarly time can be a limiting

factor. Thus, it is often necessary to establish priorities to determine what issues merit experimentation and what increments can be made to the process without any empirical studies. Some issues that might be considered include:

- Frequently a team's experience will provide them with good judgement on how to tailor a process for a specific type of application, customer, or environment. Of course one needs to realise that intuition can be misleading.
- One might view altering the process with or without empirical study as a risk management problem. For instance, small increments in the process that are fairly well-understood likely introduce little risk to the project whereas radical process changes that are poorly understood introduce significant risk.
- In many cases the technology is moving too rapidly to have the luxury of understanding the effects of a new technology before it has to be introduced into the process because of market considerations.
- It is not cost-effective to study "short-lived" issues. For instance, September of 1999 would be a poor time to undertake a 6-month study of the effectiveness of some technology to identify sources of Y2K problems in code.

Towards Process Understanding

As mentioned earlier, process understanding is aimed at building a foundation for process engineering. Thus, different issues become important when designing experiments aimed at process understanding rather than simply improving a given process. Some items are:

- Focus on core issues. For instance, configuration management will always be with us. Specific tools are likely to come and go.
- Embrace the human factor rather than denying it. It is important to realise that many aspects of software engineering are more like the social sciences than the physical sciences or engineering. Unfortunately most software engineers and most involved in process engineering research have little or no social science training. One approach to alleviating some of these issues is to rely on more collaboration between software engineering researchers and social scientists. Embracing the human elements means identifying ways to learn from the human aspects rather than trying to simply ignore them or factor them out. As an example, much might be learned from a long-term study that followed specific developers through their career. This would provide researchers with a cross-section of different processes and a window to environments. This type of study could lead to a much richer understanding of the interactions of the multitude of environments and experiences that a developer would encounter. Identifying how to maintain the long-term productivity of developers is likely to have a much more profound impact on the overall productivity of developers than focusing on the impact of some new tool in a given environment.

- A likely combination to lead to fruitful research is the combination of industrial partners and academic researchers. Industry partners can provide the experimental “laboratory” and ensure a focus on “real” problems. Academicians can bring a longer-term focus to the identification of problems to be studied. Establishing this type of relationship requires some skill and planning. Of particular importance is the beginning of the relationship. Like most relationships an early success can go a long way to build confidence and trust in each other. Thus, for instance, it is important that the first project have a high probability of success. To the industrial partners, success means a piece of knowledge that can be applied to the process. For example, success might mean an identification of a technique that will increase the identification of faults or success might mean “proof” that an expensive technology that looked extremely positive on the surface is shown to be ineffective. Hence, the cost of the technology need not be incurred. For researchers, success might mean obtaining a publishable result. Being aware of and considering these somewhat different goals can go a long way to foster a productive industry/academic partnership. If researchers know that for the most part they will not be hindered from publishing their results, they can be co-operative on other aspects of the joint venture. If developers actually see useful results come from the additional effort that is required of them when they are involved in a project, they will be more co-operative participants in future studies. It is often the case that having a senior, respected developer on-board and enthusiastic about the study will have a positive influence on the other participants. However, when growth in the industry is phenomenal and technology changes rapidly, the current respected guru may soon be overshadowed by someone else. Thus, it may be difficult for researchers to maintain the appropriate contacts.
- Study the process improvement process. A quick examination of the current process improvement process in most environments and as a discipline would likely lead one to determine that it is an ad hoc process with an unpredictable outcome. Thus, if one were to apply CMM levels to this process, we would have to place it at Level 1. Even in many cases where an organisation is producing software using a much higher development level process, it is likely that the process improvement process is still fairly ad hoc.

Conclusion

An attempt to identify the appropriate role of empirical studies in process improvement can point out the complexity of this question. There are economic issues and the need to balance between spending too much time and money with learning how to do things right. In addition, there is the human factor. Process engineering clearly contains elements of social science. Yet the background and training of most doing software process engineering is that of the scientist or engineer. In addition, process engineering and software engineering are very young fields. As such there isn't any real knowledge or understanding of the foundations of process engineering. Complicating that is the fact that software process engineering is dealing with a moving and mutating target. The technologies used today will likely not be used tomorrow; the people on a project today will likely be different

tomorrow. Finally, there are two competing goals. Industry wants and needs short-term answers to help their productivity as soon as possible, but the real aim of research should be long-term. Ultimately the most gain will be made after there is a much more fundamental understanding of software processes.

Solutions to these problems will likely come through collaborations. The production community and the research community need to cooperate in order to get meaningful answers. To do this, mutual respect and understanding are necessary. Each group needs to be aware of and accept the goals of the other. And both must acknowledge and accept the possibility and value of mistakes. Collaborations with social scientists may lead to some better-designed empirical studies that more effectively incorporate the human aspect. In particular, long-term studies that allow a window into the environment through the people involved may provide most informative results. In some sense people are one of the few constants in the field.

In summary, real progress from empirical studies concerned with process improvement will come when the studies are conducted in a more formalised fashion focusing on establishing a foundation for this young field. Obtaining this foundation will likely involve examining more long-term aspects of the problem, e.g., people issues and issues concerning areas such as testing, and will likely not involve technology issues since the technologies change so rapidly.