M. C. Ohlsson and C. Wohlin, "Process Improvement within an Educational Environment", Proceedings 2nd Annual International Conference on Software Process Improvement - Research into Education and Training, Gothenburg, Sweden, August 1997.

Process Improvement within an Educational Environment

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Abstract

Process improvement is difficult to teach as it requires a firm basis in terms of a well-defined process and systematic measurement. In our large-scale software development course we are teaching process improvement using an experience base. The main improvement objective of the course is to teach improvement in terms of improved effort predictability. This also forms the basis to teach process improvement in more general terms. This paper outlines our large-scale software development course and describes how an experience factory can be implemented incrementally in an educational environment. The experience factory provides the baseline and the experience data to enable us to evaluate if we have improved or not. A Personal Software Process (PSP) course has recently been launched at the department, and it will form another perspective on process improvement. Thus, together the courses provide a comprehensive view of process improvement in software engineering. It is our belief that process improvement must be practised and the combination of a course in large-scale software development, the PSP course and the experience base provide an excellent starting point to teach software process improvement.

Keywords

Process improvement, experience factory, experience base, data collection, measurements, education.

1.0 Introduction

A key issue in process improvement is to have a firm basis in terms measurements. We have to collect measurements and use the data to identify areas for improvement. After a process change, we must continue to measure to assess if the change made us achieve our objectives. Process improvement is inherently difficult to teach in a course as improvement mostly is concerned with long term issues, i.e. we need a baseline to evaluate a change against. Thus, to teach improvement, we must provide measurements to the students and allow them to use the data and collect new data, and thus evaluate if they have improved.

To achieve the above within the educational environment, we are in the process of creating an experience base and the long term objective is to let this evolve into an experience factory organisation [1]. The experience base should be used to provide input data to the students in the planning process of a large-scale software development project within one of our courses. The main improvement goal is to improve the predictability of the effort required. Thus, the intention is that based on available data the students are

able to plan the current project, and at the end of the course they are able to assess whether they did better this year than previous years in terms of improvement. Although, this approach does not cover all aspects of improvement and of process improvement in particular, it exemplifies improvement and provides a suitable basis to talk about improvements and to teach it constructively.

The objective of this paper is to outline the large-scale software development course, and discuss how we in a number of steps improve the basis for effort estimation in the project conducted by the students within the course. The experience base is implemented incrementally, and the outcome of the different steps are evaluated carefully through treating the introduction as an experiment. The paper addresses issues related to introducing an experience base in general, and in an educational environment in particular. The paper provides a stepwise proposal for introducing an experience base or an experience factory. This stepwise procedure forms the basis for teaching improvements in terms of improved effort predictability.

Furthermore, the objective is to create an experience base for the data collected in the Personal Software Process (PSP) [2] given at the department. The PSP is a good complement to the approach adopted in the large-scale software development course. In the PSP course the students work actively throughout the course to improve their personal software process. The PSP course is in itself an improvement course, but we would like to emphasize the improvement perspective even further through the experience base. The data from the previous year can be used as a basis for discussing process improvement, i.e. before the students practice the different process steps in the personal software process. This is so far on the planning stage as the course has recently been run for the first time with 70 Masters students taking the course.

The paper is organised as follows. In Section 2, our large-scale software development course is described in some depth, and in Section 3 an incremental introduction of an experience factory is discussed. Some general challenges in implementing an experience factory are addressed in Section 4. Section 5 describes how we intend to solve some of the challenges identified in our particular environment. Finally, in Section 6 some information is provided concerning the newly introduced PSP course and Section 7 provides some conclusions based on our experience.

2.0 Large-Scale Software Development Course

The course is a software development course conducted by the department of Communication Systems [3]. It is given in the autumn and 120 to 150 students attend every year. Their main task is to develop a number of telephone services and the focus of the course is the development process. The students are divided into groups of 15 to 19 person, forming a project, and all the projects develop the same services. This means that we can collect experiences from six to seven projects, running in parallel, every year.

2.1 Process Model

The process model used is a simplified version of the DoD-2167 A [4], which is a waterfall based model (see figure 1). The baselines in the model are emphasized to provide checkpoints in the process.
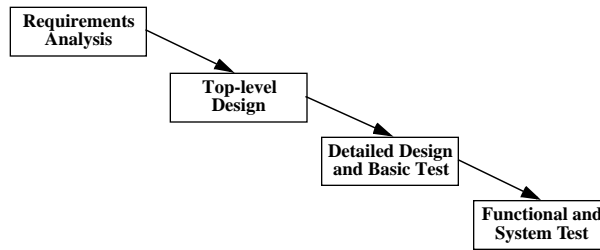
FIGURE 1. The development model

2.2 Services

The students base their development on the software for normal telephone calls and extend this system with additional services to the subscribers of the exchange. The students should develop the following four services:

- Call Forwarding Unconditional

- Take Call

- Debiting and

- Maintenance

Maintenance includes adding and deleting subscribers. It also includes changing telephone numbers. A differentiation from real projects is that the customers' requirements (our requirements) are mostly straightforward compared to the fuzzy requirements found elsewhere, and they are stable throughout the course.

No information about erroneous interaction cases and special cases is provided. Instead, these should be specified by the students and communicated to the customer.

2.3 Organization

As mentioned earlier the projects consist of about 15 to 19 students and the projects are divided into eight subgroups (see figure 2). Ideally there are two persons in each subgroup except the system group where there should be three persons. The project leader group acts as project leaders, the system group is responsible for configuration management and overall system structure, four of the subgroups are development groups and each one of these develops one service, and finally two subgroups which act as test groups testing two services each. The test groups also perform the system test together.
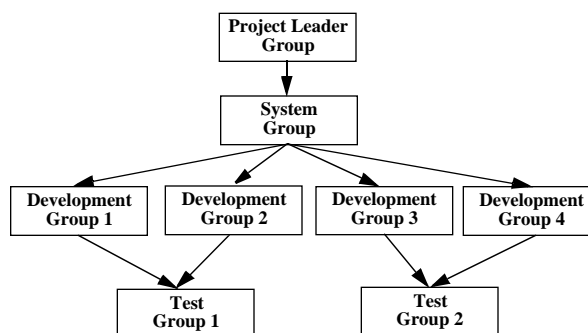

FIGURE 2. Organizational structure of the projects

The roles of the subgroups are combined with roles played by department personnel. These roles are, including the role of customer, external quality assurance personnel and technical experts. The customer reviews the produced material at two times during the project and the customer also performs an acceptance test at the end of the project. It should be noted that executing the process correctly is as important as the quality of the final product.

3.0 Incremental Introduction of an Experience Factory

Our intention is to construct an experience factory and see if this way of working can function in a university environment, and what we can learn to introduce it into an industrial environment. Also, the students learn how to work with process improvement and as the experience factory evolves, the students gain greater insight and will therefore also work more actively with process improvement. They will able to improve data collection, analysis of data, and based on this suggest improvements and introduce changes. The experience factory concept is a natural way of working with process improvement and it is closely related to the Quality Improvement Paradigm [1] and together this forms a solid base for working with process improvement.

A major benefit, from using the course as a study object, is that it provides us with a homogenous environment from year to year. There are few variables changing, for example, the students have the same educational background, requirements are the same and the changes to the course are controlled. Therefore, if we cannot manage to make better estimates by collecting and processing data from very similar projects, it is not probable that it will work in an industrial environment.

By implementing the experience factory incrementally, we will have control over the development of it. Also, it provides us with the ability to solve problems as they arise and evaluate issues like, for example, how the students take advantage of the information in the experience base. Evaluation and feedback are necessary for learning [1]. As the experience factory evolves incrementally we can make decisions about what the experience base should contain and sort out information not used.

3.1 Experimental Plan

To move towards the experience factory, a four step program have been introduced [3][5]. The base for this program is that the projects are given a certain input for planning purposes, from the experience base. They are also asked to collect certain data, which at the end of the course are added to the experience base. The four steps are the following:

- Rough figure to informal experience base
- Informal experience base to template based experience base
- Template based experience base to formalized experience base
- Formalized experience base to extended formalized experience base

In the first step no experience base is available when the projects start. The projects are only supplied with a rough figure regarding the expected effort needed to conduct the project and a recommendation of reporting format for the data. This step was conducted in 1995 and the objective was to evaluate if the estimates of effort would have been better if six of the projects had been in an informal experience base [3].

The second step provides the projects with the experience base from the first step. Though, the projects are not provided any particular training for using it. Templates for reporting data consistently are handed out and the objective of this is to evaluate if the outcome is better than in the first step. The same evaluation as made in step one should also be performed here [5].

In the third step the experience base from step two is made fully available to the projects. Also, the project leaders will receive training and information concerning project planning using the experience base. The training will be conducted in one group to ensure that the project leaders have equal knowledge of the estimation method to apply. Also, they are expected to involve the rest of their project groups in the planning to obtain commitment for the plan. Finally, different people, playing the roles in an experience factory, should support the projects.

The last step, step four, includes the full use of the experience base and we evaluate if the predictability of effort increases as the formalization of the experience factory and experience base increases. An experience factory should be created with people from the projects and they should be educated in maintaining the experience base and supporting the projects.

4.0 Some Challenges in Introducing an Experience Factory

Although we have a controlled environment there are problems that have to be solved. This is valid from the beginning of step one and onwards.

4.1 Data Collection

The data are the base for the experience factory and therefore it is important to collect and analyse the necessary data and in as formalized and heterogeneous way as possible [6]. Neither should it be time consuming for the projects because then the reporting of the data will be set aside and they will focus their effort on the development of the services instead, because this is probably more substantial for them.

4.1.1 Usefulness and Reliability of Data

It is very easy to collect too much data. Most of the collected data is probably useless and it is not possible to draw any qualitative conclusions. The result will be that time is spent on activities that give the projects nothing in return. Also, the size of the experience base can grow to sizes that are not possible to manage.

The lack of motivation among the students could also be a possible source for less reliable data [3]. If they cannot see the benefits of the work they might not be so careful in their collection, analysis and estimation.

4.1.2 Educational Background

In some organizations there have been problems with inexperienced people who do not see the usefulness of the work and sometimes they are not familiar with the way of working.

According to our experience, another problem is that people, i.e the project leaders, make rashed and unfounded assumption about which data they need to make some form of analysis or draw some conclusions. Later when this data have been collected

and should be used, they have found that it has not been possible to make the required analysis due to the fact that the data did not allow for answering the questions in mind.

The problems are based on the fact that the people who do these statements often do not have the necessary understanding and knowledge for working with metrics. Therefore, people just think it is possible for them to do the estimates if they have, what they think are, the necessary figures. The goals and assumptions are not analysed and grounded.

4.1.3 Perpetual Data

The only problems with the data are not only the usability and the reliability. Also, we must ask for how long time the data are valid. It is very important to have valid data if it should be possible to make accurate estimations [2]. This is also true for the artefacts that should be reused.

As the students previous knowledge changes, the data in the experience factory become invalid. The data might be to basic so that the conclusions that could be found in an analysis are already known or easily could be found. Instead, the data should support them in making better project plans and size estimations. The experience base should therefore contain the information that not could easily be concluded.

When the students become better in making estimates with help of the experience factory, the new data stored in the experience base will be more accurate. If the data from the first projects are used, average values and other statistical calculations will be less accurate. So, how do we know when the data in the experience base are inaccurate?

Also, there exists a physical problem. As long as we just continue to fill the experience base with more and more data it will grow. This may lead to problems maintaining it and the performance will decrease. Again, this will affect the use of the experience base, and the motivation for using it will decrease.

4.2 Organization of the Experience Factory

An experience factory consists of the experience base and the organization, maintaining the experience base [1].
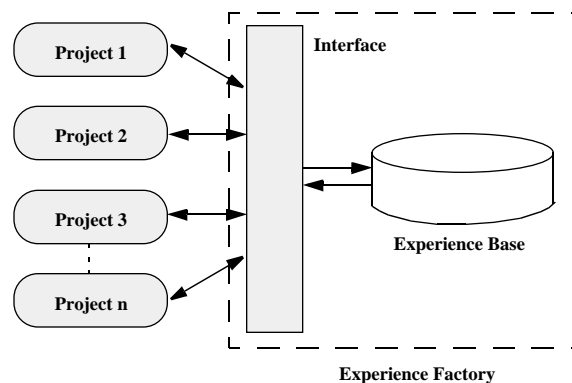

FIGURE 3. Experience factory parts

Within both these parts (see figure 3) there exists problems that have to be solved.

4.2.1 Experience Base

As mentioned earlier, it is necessary to collect the right data and this data differ from organization to organization. This means that different organizations will collect different data and generate different experiences which will be stored and packaged in different ways. Depending on this, the experience base has to be configured differently but in such a way that it possible to extend it [1]. It should be easy to handle. If the interface to this organizational memory is difficult to deal with, no new experiences will be added and the experience base will not be used as intended.

4.2.2 Availability

If everyone in a project has access to the experience base and has the opportunity to add new data or artefacts, it will soon be very unstructured and inconsistent. This will mean that the opportunities to find the relevant data greatly are reduced.

Depending on the responsibilities different persons have, different restrictions concerning their ability to access the experience base should be applied. Also, these restrictions depend on the organizational structure.

4.2.3 Organizational Structure

Depending on the size of the organization the structure of the experience factory and its process will look different [7]. Is it necessary to have a separate department, an experience factory, to maintain the experience base? It takes resources to run an experience factory but this has to be evaluated against the advantages. This question is also related to the size of the organization and what they want to achieve with the experience base.

Also, within the experience factory there exists organizational problems. The questions about how many persons should form the experience factory and what their responsibilities should be, have to be answered. Another problem is which projects, the experience factory should support and if there should exist experience factories with different types of responsibilities.

Finally, depending on the intentions of the experience base, what it should be used for and what should be stored, the experience factory has to accomplish different tasks and these must be defined.

4.3 Implementation

As always with new things they will be met with scepticism, but the introduction and implementation will be made easier if things are introduced in a careful way. The persons involved in the projects have to be committed and it is necessary to show them the benefits of doing the necessary work related to the execution of an experience factory. It is therefore important that the organizations find suitable ways for introducing these new concepts.

5.0 Proposed Solutions in our Educational Environment

Some of the difficulties discussed in "4.0 Some Challenges in Introducing an Experience Factory" can be foreseen because of the nature of the experimental environment, but many of them have to be solved. The proposed solutions are related to the four steps in the incremental introduction of an experience factory and should be implemented according to them.

The students have studied three years at the university before they attend the course. This means that they have the necessary educational background and understand the work with metrics. To pass the course, the students have to perform all the activities that are specified, it is not enough to deliver a working system. Therefore, the students are inclined to perform all the desired activities.

5.1 Forms

To collect the necessary measures, verify the quality of the produced artefacts and to control the process, we have created forms based on a small GQM evaluation [6][8][9]. The measures that should be collected are also inspired by the PSP [2]. They are very basic, but they provide necessary information to be able to perform an extended or deeper analysis.

By using these forms we will have a formalized way to report necessary information (see figure 4). We provide a description of how the forms should be used, including examples, and they receive education related to the use of them. This leads to consistent reporting and the information could be added to the experience base.
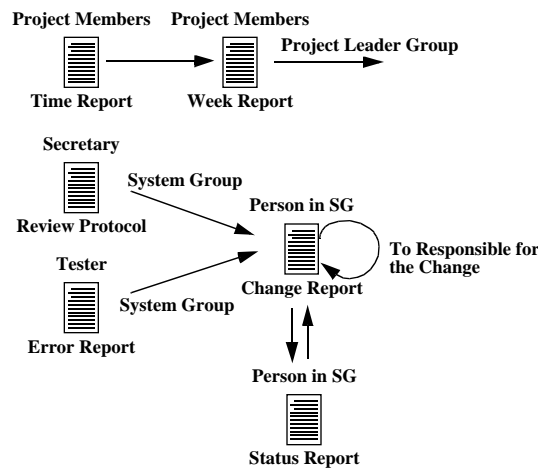

FIGURE 4. Distribution of documents

5.2 Organization of an Experience Factory

The idealistic situation is if we could form projects groups with 17 persons. This seldom occurs and therefore we have to create suitable groups so that they are as similar as possible. Instead of doing this some persons could form the experience factory. According to this we have identified four possible organizational structures and they assume a common experience factory so all projects could take advantage of the data.

- Personnel from the department forms and maintains the experience factory and educate the project leaders in using it.

- One person from each project leader group forms the experience factory and work with it part time.

- One person from each project leader group and one person from each system group forms the experience factory and work with it part time.

- Two to three persons form an experience factory and are only working with the experience factory.

5.2.1 Department Based Experience Factory

The synthesis and analysis activities should not be performed by the students themselves. The personnel at the department will help them and guide them trough difficulties. This is because it is hard to perform these activities without any previous knowledge about how it should be done and mainly, what should be done.

The base for the experience factory is therefore created by us in the background, i.e. the students are not aware of that we use the data from the projects to create an experience base. Also, we do our own analysis and synthesis of the collected data to improve the experience base and the course.

5.2.2 Project Leader Based Experience Factory

The project leaders are those who first of all, according to the incremental introduction of an experience factory, needs access to the information in the experience base and they are also reporting data. Therefore, one person from each project leader group could form the experience factory. They know which information they need and they receive much of the figures directly from the projects. This avoids overhead working with the experience base.

The disadvantage of this alternative is that it will involve seven to nine persons and it is therefore necessary to have well defined responsibilities within the experience factory. Otherwise, the work with the experience base will be chaotic and it will be inconsistent.

5.2.3 Combined Discipline Experience Factory

In a short perspective the project leader groups and the system groups are collecting data for the experience base. Though it is just the project leader groups that will use the information.

If we instead have a longer perspective and think about changing the course by letting the projects develop different services. Then they could reuse different parts from earlier projects. The experience base should then be used to store code and other artefacts as well as experience in terms of metrics. The system group will use the experience factory searching for reusable items. This means that the system groups have a desire to control the content of the experience base, or at least parts of it. Therefore, a possible solution could be to use persons from both the project leader groups and the system groups.

Just like the project leader based experience factory there will be a lot of people involved which may lead to chaos. The advantage is that the knowledge about all the data and artefacts can be found within the experience factory.

5.2.4 Free Standing Experience Factory

The free standing experience base should consist of two or three persons whom should only maintain the experience factory and support the projects with the desired information. The advantage of such an organization is that we will have a few people that are totally dedicated to the work and these are the only persons who have write access to the experience base and therefore it is easier to keep it consistent. Also, we will always know who is responsible for the experience factory and the services it should provide.

With an organization like this we have the disadvantage that the persons working in the experience factory do not have insight into the projects and they cannot really see their needs. Much information need to be exchanged between the project leader group, the system group and the experience factory. This can lead to misunderstandings and misinterpretations.

5.2.5 Recommendation

When the informal experience base is founded we think that the most suitable organizational structure of the experience factory is the department based one. This should be created at step two and evolve to the free standing at step four. The reason for this is that at step two it is necessary to do it incrementally and partly increase the formalization of the experience factory.

At step four the experience factory should be fully developed and the only alternative is a completely separated department so it could be developed further without too much involvement from the projects, i.e. the technical aspect of the experience base and the activities performed by the experience factory, become more and more advanced.

5.3 Physical Structure

At the first steps of the creation, the physical structure of the experience base does not need to be so technical advanced. This is because of the nature of the information. It is just pure figures that has to be analysed and to hold this information a spread sheet or a simple database is enough.

When we later evolve towards the experience base and the tool supported reporting, there exists a need for a more advanced experience base. This is also true if the projects should reuse code, aside from the main system, and other artefacts. Though, this is only true if we decide to change the course in this direction.

5.4 Activities

Even though the organizations look different, they work performed should be the same. The experience factory should:

- Collect and gather data that should be stored in the experience base.

- Synthesize the collected data so it is generalized and made reusable.

- Analyse the data to provide the projects with useful information and to identify other data that have to be collected or data that should not been collected.

- Support the project with the desired information from the experience base.

5.5 Validity of Data

To solve the problem with invalid data, it is necessary to implement methods within the experience factory for maintaining the validity of the experience factory. Every time a project is finished and they have reported all their data, an evaluation has to be done to compare the planned figures, the real figures and those in the experience base, to see if the planning has improved or, in worst case, has become very inaccurate. The correlation between these figures could be calculated to see if they are useful when trying to make new estimates or they just should form an experience. Other statistical calculations like standard deviation could also be used.

If the experience base includes artefacts of different kinds, it is necessary to control this too. A solution could be to mark the artefacts with a date mark when it was included and a history or log function that keeps track of how many times the artefact has been reused and when it occurred.

6.0 The PSP Course

The PSP course is based on W.S. Humphrey's Personal Software Process concept [2]. This is the other course, given at the Department of Communications Systems, concerning process improvement. Between 70 to 90 students attend the course and the goal is to improve their personal software process and the accuracy of their estimates for developing new programs. This is done with help of historical data, their personal experience base and a stepwise improved process. All the work is done individually but during the course we give feedback on every exercise and at the end of the course a summary of different statistics showing the students' performance is presented.

The idea with this course is to educate the use of processes and processes improvement by scaling down the processes to a personal level and then using a number of software development projects to work with the processes. The students should learn that it is necessary to know what to do, when to do it and how to do it. All this to be able to work effectively and predictable. Also, they should learn how to understand and improve processes through measurement and analysis of collected data. Furthermore, they should understand the difficulties in measuring attributes depending on people.

During the ten assignments the students produce and collect data. This data form their personal experience bases and should be used to improve their personal software processes. The analysis of their data lead to a better understanding of how they work and how different processes function. Also, it helps them see their weaknesses and suggest possible improvements to their personal processes. The process understanding is helpful and almost a requirement when scaling up the process in larger projects.

When the course is finished, the data from the students projects should be stored in an experience base and it should be used as input to illustrate process improvement the next time we run the course. Also, this provides an understanding of the experience factory concept where these activities are a part of the concept, i.e. collect and analyse data and then reuse the results and findings in future projects. It is possible to look at it as the students are their own experience factories and before they execute a new project they take advantage of their own experiences from earlier assignments. As mentioned, the activities are the same as in an experience factory even though the students are more restricted in their abilities to improve the processes, but still they have to analyse and suggest improvements and for some activities the students have to improve and refine the process.

7.0 Conclusion

There exists many different approaches for working with processes and process improvement. At the Department of Communication System, we have chosen to focus on theory combined with a large amount of practical work. This provides a better understanding and insight into the work with processes and process improvement. Therefore, the students will be well prepared when they enter the industrial environment and they will also be prepared to work with continuous process change.

To a great deal, this depends on our two-way approach to educate process management and process improvement. From a large-scale perspective the students learn how to work in software development projects when the projects consist of between 15 to 19 persons working together to develop a system. From the students personal perspective, they learn how to adapt new ideas, techniques and methods in a rational and controlled manner and their basic conditions for software development. To be able to work with these activities it is necessary to collect, store and analyse process data and this is supported by the use of experience bases and the concept of experience factories.

Finally, the large-scale software development course and the PSP course together with the experience factory concept provide a framework and an important foundation to teach software process improvement.

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