A Case Study where PD Would Have Helped – Or Maybe Not?

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ABSTRACT
Advocators of participatory design (PD) and other user centered design methods often claim that these methods solve all problems with design. We are also PD supporters, but we believe that there are certain issues that current PD methods do not address. A case study is described where it is clear that PD would solve many of the obstacles that occurred. However, the same study also illustrates that there are some issues that no current PD method handles: industrial espionage and cost/benefit discussions that increase the profit of the company developing the product by *not* solving the users' problems. We fail to see any solutions to the problem by modifying any PD method. However, increased awareness of life cycle costs among the people who purchase products could make PD methods even more useful as well as laws that make user participation mandatory in product development.

KEYWORDS
Participatory design methods, industrial espionage, law.

INTRODUCTION
The ultimate goal of product development is to make usable products at a reasonable cost. We believe that the best way to do this is to involve the users. There are different ways to co-operate with users when new technology is being developed. If you choose to involve users in the development, different approaches can be used.

Theoretical models are important in understanding general things about us as human beings, for instance how our perception or memory functions. Standards can also be included as a set of basic level knowledge.

This will unfortunately not be enough. It is also important to meet the users.

In Usability engineering the development process is organized around system functions and the implementation of specifications. The focus is not on user co-operation but on the usability of the product. To achieve this, knowledge about users and their task is required. To reach this knowledge different techniques for collecting data can be used. Contextual design [1] is one of these approaches and it also includes the context by collecting the data in the field. This is required in order to develop an understanding of the whole complex work situation. Developers and/or researchers visit the users out in the field, but users are not invited to participate in the development.

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This will unfortunately not be enough. It is also important to co-operate with the users.

In co-operative design, a step-by-step rationalistic approach is avoided. New technology is regarded as a tool used on a work site and there is where the co-operation should take place. The users should be allowed full co-operation in the development process; after all, it is going to be their tool at their work site! Training as well as learning is an ongoing process throughout the development. All participants in the development process learn from each other and the users' competence is strengthened by this co-operation. A number of participatory design methods have been developed and a summary of these is presented in [6].

PREVIOUS PROBLEM AREAS ENCOUNTERED
It is easy to say (based on theory) how to perform user-centered design, but it is another thing to actually do it. Experiences collected during workshops with practitioners and researchers [3, 4] made us aware of problems with:

Attitudes on the different roles represented in a system development team. Who is co-operating with the users and how?

Communication When people meet in a system development team they come with different background, skills, and languages. To build a common ground within the team takes time.

Methods and tools Many methods and tools are available but are they useful and available to everybody?

Lack of time User centered design includes iterations and repeated tests, but often the lack of time makes projects skip these parts in the process.

Organization A user centered approach must be supported and encouraged by the organization and managers.

Competence Often a design team lacks knowledge and competence in HCI and human factors.

Introducing user centered design to individuals or organizations often brings up the question about what you gain with this approach. One way is to do a cost/benefit analysis [5]. In [2] an estimate of success factors in software development projects is presented. In the USA alone, 250 billion dollars were spent every year on 175 000 different IT-projects. In a survey with a total sample of 365 executive managers representing large, medium and small companies across major industry segments showed that:

- 31% of the projects were interrupted
- 53% were performed with changed plans
- 16% were performed according to plan.

The average of cost overruns across all companies were 189% of the original cost estimate. In the report it is estimated that 81 billion US dollars were spent 1995 on canceled software projects.

According to [2], the three major reasons that a project will succeed are user involvement, executive management support, and a clear statement of requirements.

As presented above, many problems can be encountered during a system development process. Many more exist and have been presented elsewhere. Below a story is told in order to give you yet another example of user and developer problems not commonly discussed in the literature.

CASE STUDY

Once upon a time there was a software engineer who just had left the sheltered university and was eager to improve the world by constructing the best software ever in machines that would be used to support people in their daily work. This little engineer ended up at a large German company's X-ray division in a Swedish city with the mission to develop real-time control systems for X-ray machines. We can call this company TechMed.

At this time a decree was distributed from Germany by the head of all TechMed X-ray departments in the world that a new mobile X-ray machine should be developed, and the task fell upon the bright and underpaid engineers in Sweden.

Normally X-ray machines are rather large and mounted to the floor or the walls of the X-ray department of a hospital. However, some patients are too sick to be moved at all, they may for example be attached to a respirator, a dialysis machine, or a heart-lung machine. In these cases the X-ray machine must come to the patient. The mobile field hospitals used by the military also have a need of mobile X-ray machines.

The concept of a mobile X-ray machine is not new. There are several companies that construct and produce them. TechMed had produced one of the most popular ones for several years, but the model had become old, so the task was not to invent anything, merely to improve an old well-functioning construction by using more modern electronics, computers, and software.

All mobile X-ray machines have approximately the same look: they look like a closed shopping trolley with the X-ray tube in an arm similar to an excavator on top of the trolley, see figure 1. The task was formulated as "build a smaller machine that is cheaper to produce, but can be charged more for, compared to the old machine".

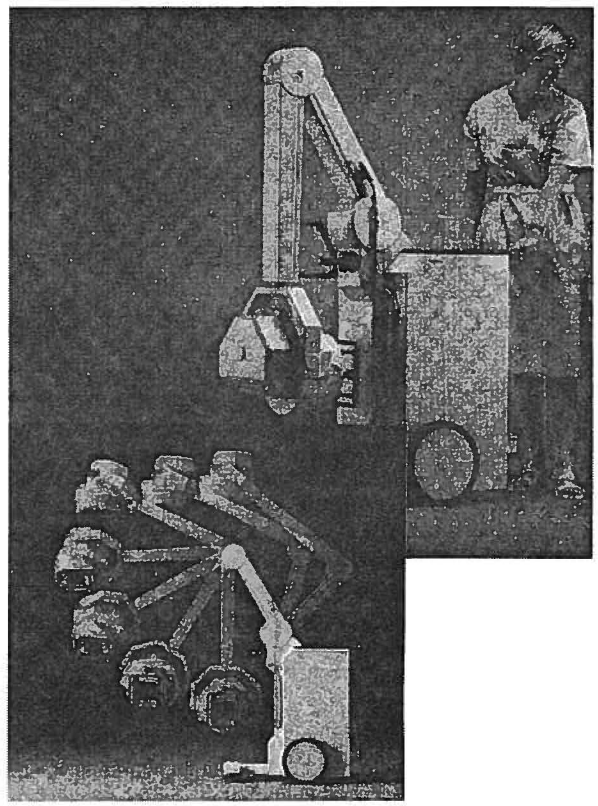

Figure 1. A mobile X-ray machine.

The bright underpaid engineers gathered at the X-ray department of TechMed in a laboratory where the sun did not shine. A person from the market department provided them with input from customers and declared it was important that measurable figures should be better or at least as good as the competitors', since the people who buy these machines do not know very much about X-ray pictures or medicine. Most people who buy things for hospitals are economists, he said, and they understand figures, which means that our job is to construct a machine that is better than our competitors' machines when compared in a table with key data such as size, weight, and recharge time.

The Analysis

The engineers had a need to do something challenging (maybe because they were underpaid and never saw the sun) so one of the ideas that came up during the design brainstorm was to use voice output instead of, or as a complement to, the liquid crystal display. This would allow the nurse to have both her eyes on the patient instead of on the machine.

One of the leading companies in sampled sound output at that time was contacted and they demonstrated their products. However, the engineers were not happy with the sound quality. The voice sounded very machine-like for the inexpensive solutions.

The final stroke against audio feedback came when the engineers realized that the display would still be necessary due to the error messages. A patient in critical condition being X-rayed may be negatively influenced error messages in a machine-like nasal voice, and since this machine would also be on the US market they could certainly count on enormous claims for damages and endless lawsuits.

Another idea was to move the display for the current strength (mAs) and tension (kV) from the shopping trolley to a hand held control panel. This would make it possible for the nurse to move around freely and set the mAs, the kV, and take the picture without walking back to the trolley. In the old version of the mobile X-ray machine the trigger was a simple button on the end of an elastic cord (similar to the cord between a telephone handset and the telephone but much thicker).

The underpaid engineers happily started the development of the improved machine. The control system consisted of four processors for the different parts: one for the hand panel, one for the generator, one for the capacitor (that stored the high voltage charge for the X-ray shot), and one for the rest of the tasks.

The Design

One cold and gray winter morning a person from the service department randomly passed by the X-ray development laboratory and had a coffee break. He told ghastly stories about the users, the X-ray nurses. Among the many things he described, this is the most relevant for the continuation of the story:

For some reason, it seems that nurses at the hospitals X-ray departments are smaller than other people. These nurses were not only smaller than the all-male population at TechMed's X-ray department, but many were also smaller than the average Swedish woman. In fact many of the X-ray nurses were so small that their weights were only about one fifth of the X-ray machines' weight. This caused some problems with inertia of motion, and was also the source of some great war stories.

The massive mobile X-ray machines were difficult to handle for a single undersized nurse. In order to get the machine moving, they must use their whole body weight to push it, and when the machine was to be stopped they must use their whole body weight again to reduce the speed gradually. Once in motion though, it was rather easy to steer the machine if you used both hands. However, doors are very common at hospitals. For those that are pushing around patients in beds, or X-ray machines, there are strings attached to a switch in the roof that will open the door when the string is pulled. This seems like a good idea, but since the X-ray machine is both hard to brake and to steer with one hand (while the other is pulling the door-opening string), X-ray machines occasionally run into doors that do not open in time, or open towards the oncoming machine.

For hospital beds this is not so problematic (unless you think about the patient, but these beds are mostly controlled by men that are about 50-70% heavier than the X-ray nurses). For X-ray machines designed like this one, this is a catastrophe. At the end of the excavator arm is the X-ray tube. The tube contains approximately two liters of vacuum and is mostly made of glass. For some reason, still unknown to the non-mechanical engineers involved, this tube was supposed to be fastened at the front of the X-ray machine, which of course transforms the X-ray tube into a ram and a deformation zone. Totally unrelated to this story is the fact that TechMed's service department, against a fee, replaces broken X-ray tubes. Or maybe it is related.

One of the heroic engineers in this story suggested that if they could not change the design to move the X-ray tube out of the collision zone, maybe they could add a bumper to the front to protect the X-ray tube at least from direct hits. Everybody laughed at this suggestion and the heroic engineer no longer works for TechMed.

The same heroic engineer also suggested that the machine could be equipped with a motor drive and brakes to diminish the problems with pushing and pulling. At first management claimed that this would increase the weight, and thereby increase the mobility problems even more when the motor was not running, but after a while the management admitted that a motor should be added to the machine as an option. The main reason for this was not that it was a good idea, but the fact that the carpets on hospital floors in the USA made it impossible to move our machine at all (but on the other hand solved the problems with braking). The management had planned for a motor drive from the beginning, but this was a "strategic function" of the machine and had been kept secret from the competitors. It was also too secret to be handled by TechMed's personnel, so the design of the motor drive was handled entirely by a consulting company.

Also in secret, the marketing department invited a handful of trustworthy X-ray nurses to beta-test the machine one evening at TechMed's laboratories. Besides the marketing department, only the project leader was invited from TechMed. According to the reports, the nurses were pleased with the new machine and the dinner that followed.

The Field-test

One sunny April morning, the day had come for the new X-ray machine to be field tested at a real hospital with real X-ray nurses and real patients. It flopped. There were several reasons for this.

The complex control system with four communicating processors made the system somewhat unstable, and after it malfunctioned once, the nurses who were very busy and did not have any extra time to take more pictures just for our sake, avoided the machine.

Figure 2. Picture of an average Swedish male engineer and a simulated X-ray nurse. The hospital in the picture has nothing to do with the story.

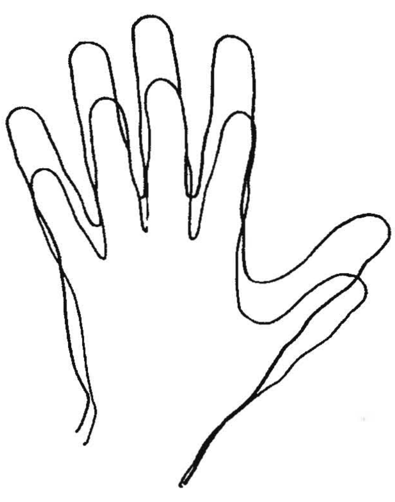

Figure 3. Silhouette of the average Swedish male engineer's hand and the corresponding X-ray nurse's hand.

The hand held control panel worked fine for the average sized male Swedish engineers, but not for the small sized female X-ray nurses (see figure 2) with hands approximately half the size of the engineers (see figure 3). These nurses needed two hands just to hold the control panel, and unless they mutated in the X-ray department, they had no hands free to push the buttons.

Due to the processor in the control panel, the cord between the control panel and the machine needed five separate cords (two for power supply, two for communication, and one ground). Due to safety regulations the insulation of these cords was extra thick. All this resulted in a cord that was both expensive and heavy, and when the nurses managed to carry the control panel to the patient, the elastic cord provided a force in the opposite direction which could pull the nurse back to the X-ray machine.

In fact, the whole idea that the nurse would like to stand beside the patient when taking X-ray pictures is insane. If anything, the nurse would most of all like to leave the room in order to avoid the radiation.

Relations to Participatory Design

It is very easy to see how PD would improve the design since several obvious mistakes were made. Of course some of these mistakes would never have happened if the engineers had e.g. made some "quick-and-dirty" ethnography. Even if they had followed a nurse around for just one day, they would have noticed several major differences between the sheltered environment in the laboratory and the real life at the hospital. The problems of opening doors with the X-ray tube as a ram could then be explained and not only laughed at. The size of the hand held control panel would be more obvious in the hand of a nurse, compared to one of the engineers.

Some of these problems are methodological. The company did try to get end-user input from the nurses by inviting them to the company, so the ideas of user input and involving end users was not unfamiliar, but nobody had heard of any of the terms "participatory design", "user-centered design", or the "Scandinavian approach".

The problem with the doors did surface long before the design was "finished". It was, however, ignored due to the vast differences in culture. For the engineers, the fragile X-ray tube was the main thing to protect. For the X-ray nurses getting the machine to the patient in time was the main thing. TechMed was lacking an adequate method to capture input from the users and use that in the design.

However, there are other problems that are not so easy to solve. A year after the failed field test, a decision was finally taken to reconstruct the machine. The hand held control panel with one micro-controller was replaced with a one-button trigger, very similar to the button on the old machine. The controller of the tube was replaced with a dedicated signal controller, specialized for measuring and controlling. The two remaining controllers were replaced by one and the improved new machine became a market success, despite the remaining user problems with high weight and breaking tubes.

Why? The non-Marxist company's main goal was to make as much money as possible. They knew from long experience that the main reasons that sold machines was reliability and low prices. If the machine does the work, and is cheaper than its competitors, it will sell. Nobody cares about the nurses, since they do not order machines, but only use them. Also, broken tubes that have to be replaced is not a bad thing for the company that produces the only X-ray tubes that fit the machine. The company's service department is also a profitable organization. The customer in this case is so large that the money for purchase of new machines comes from a different pocket than the money that pays for service, and the money for rehabilitating nurses from a third pocket. The only way we can see to solve this (besides creating a Utopian society where everybody always puts the good for the society first) is by law that makes it mandatory to use participatory design methods.

Also, there is a problem not mentioned yet in the story: companies do not want their products to be known by their competitors in advance. This works against user participation. As soon as the X-ray machine was placed at the hospital for the field tests, all major competitors came there to have a look. TechMed had to place a man by the X-ray machine to prevent them from opening the machine and revealing the structure inside. However, they could not guard the machine 24 hours a day. There is always a possibility of buying silence, but in this case they would have to buy silence from several people involved who had access to the machine at the hospital. The TechMed competitors needed only one non-Marxist person with mortgage problems.

CONCLUSIONS

We have illustrated the incompleteness of PD by telling a true story of the development of a mobile X-ray machine in a medical company. The story gives several examples of how PD could contribute to improved design for the users and reduced cost for the developers. However, two of the mentioned problems cannot be solved by PD alone, if at all: rational moneymaking and industrial espionage.

When it comes to moneymaking decisions companies will ignore the Utopian goals of PD in order to increase profits. The goal is not to produce the best product, but a product that is good enough. The fear of industrial espionage work against user testing in a real environment.

Can PD change to address these problems? Probably not, but maybe we can change the environment to fit PD for the better of the society as a whole.

When it comes to cost benefit analysis, Karat [5] has already done a great job of showing that PD is cost justifiable and can result in increased sales and revenue, user satisfaction and productivity, significant cost-avoidance in training and support, service, personnel, and maintenance. Also, the Standish group presents results indicating the importance of user involvement for the success of a project [2]. The problem with industrial espionage, also briefly mentioned in [7], is real and impossible to influence with changes in PD methods. Competitors will always have an advantage if they have information and will therefore always seek information about their competitors' products and processes. Monopoly might work, but regardless of if it is a commercial or government controlled company, we would not advocate that.

We can only see two remedies to this problem with industrial espionage: increased awareness of the importance of PD by the people who order products and laws that make it mandatory to use PD, for example co-determination laws.

Capitalistic organizations will buy the product that fulfills their needs at the lowest possible cost. If PD and Capitalism should work together, the cost of the whole product life cycle must be visible, including maintenance, disposal, and injuries and damages the product will induce.

If this fails, our only hope is to influence governments to make PD a mandatory requirement in development and as a condition for approval by purchasers.

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