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RESEARCH APPROACHES ON PRODUCT DEVELOPMENT PROCESSES

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1. Introduction

Product design/development deals with different aspects on how to bring forward new or re-engineered products. When the product is ready, it is supposed to go into the production *process*. Developing a new product is being developed that is also a part in an innovation process performed as an innovation project. The development process of a product is in general performed as a *project* (making something unique). Innovation projects often have no clear time or cost limits simply as it is impossible to set such limits before the project starts and until the first products have been sold and taken in use (Ottosson 1999-B, Holmdahl 2006).

Industrial design and engineering design are two important subsets for which in turn different tools are used. Other subsets of product development are production development, market development, sales, and project management. To shorten time to market and to increase user satisfaction, integrated project teams (Olsson 1985) are used with representatives from the different specialities. Depending on the management principles used traditional/classical principles as Stage-Gate™ - SG (Cooper 1998, 2002, 2005) and Integrated Product Development – IPD (Olsson 1985, Andreasen & Hein 1987, Ehrlenspiel 1997) or dynamic principles as Dynamic Product Development - DPD (e.g. Ottosson 2004) are used.

There are two main purposes for making research on product development processes that need to be combined for an optimal payback: a scientific and a practical purpose. The scientific part is either to make testable propositions followed by generalising from emperical investigations or to study the reality and generalise from the findings. A combination of these two extremes is also possible. The practical part is to improve the usability in methods and tools for the product developers. Being more effective and more efficient in product design activities and gaining user satisfaction from the users usually means commercial benefits for the company.

Product development processes are complex, which means that they change with time and often in an unplanned or unforeseen manner. Every development project also contains many interacting factors (see figure 1). If the researcher has former experience from the actual field she/he will in general have better possibilities to understand and contribute to the science and art of product development.

Research on product development processes is in general conducted either from a management point of view or from a technical engineering point of view (Ottosson 2005). A combination of the two perspectives would add a holistic view to the research.

The American organisation PDMA - Product Development & Management Association (www.pdma.org) is an example of an organisation discussing the management point of view, also producing Journal of Product Innovation Management. The technical approach is focused e.g. by the Design Society (www.designsociety.org). Connected to the Design Society is Journal of Engineering Design. A journal with a more mixed focus between the two extremes is Technovation.

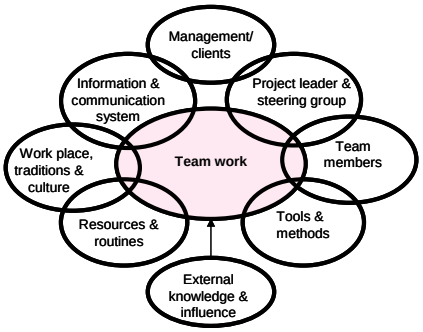

Figure 1. Product development is dependent on and influenced by many factors that in turn are time dependent. Some important factors are shown in the figure (Ottosson 2005)

1.1 Research from a management point of view

So far an outsider perspective using a quantitative research approach has been dominant for researchers studying the management perspective on development processes. The main data collecting method used is making surveys – sending out questionnaires by mail or e-mail – as such studies are relatively quickly done and cheap to do (Jönsson 2004). In turn questionnaires can be used in two principle different ways (see figure 2); sending out questionnaires to many companies targeting one person per company, or sending questionnaires to a few companies targeting several persons per company. The important difference between the two alternatives is that in the first case one obtains one measurement of many different objects, and in the second case one obtains many measures of few objects.

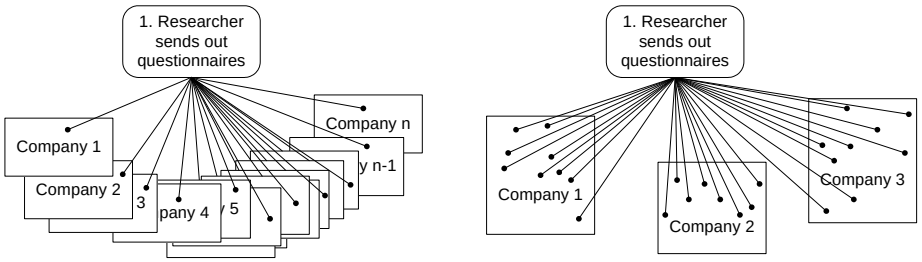

Figure 2. There is a quality difference between sending questionnaires to one person per company compared to sending to many persons per company (Holmdahl 2006)

As every development project is unique the left alternative in figure 2 is questionable to use. Asking only one individual from each project then mixing the answers is like measuring the resistivity of many different metals and then giving an average value for the resistivity of all metals, which is of no practical value. The right alternative in figure 2 however can give useful insights. Extremely important in that case is to look for that the response rate is high. Although well known, the lower the response rate the higher the probability of non-response error (Eaden et al 1999) – which does not seem to bother many researchers in our field. Poor response rates will lead to bias because some groups are less likely to fill in a questionnaire than others (Williams 2003). A response rate lower than 90% will bias the results (Marshall 2005). At response rates of less than 60% it is very difficult to interpret the results at all (Huston 1996). Despite this, lower response rates unfortunately are quite common in scientific journals.

The result of the questionnaires is dependent on many things. Often mentioned as shortcomings are the difficulty in formulating questions and low responding rates. However, the mood, the interest, and the motivation of the respondents are seldom discussed even if these factors might have a considerable effect on the result. The understanding of terms used and how much time respondents have had to set off for answering are other factors that might have effects on the result. In addition, there might be

political reasons for answering the questions in a tactical way. The reliability in research findings where the purpose has been to in some way increase the understanding of complex processes based on surveys however will be low even with rather high response rates if the left alternative in figure 2 is used.
Interviews can be conducted in several ways; first as structured which is an approach much like the survey except for the presence of the researcher. Second, as semi-structured which gives opportunities to free comments from the respondent, and finally the third alternative, which is the free interview, that is more like an open dialogue between the researcher and the respondent. Interviews instead of surveys might improve the situation as misunderstandings can be reduced when the researcher is present personally or by phone. This as the researcher will normalize the subjective answers of each respondent giving a more reliable result (Ottosson 1999). To note however is that the researcher's understanding and experience of the context will influece the reliability of the interviews. Björk (2003) argued for that readers of research papers benefit from knowledge of the researcher's background and loyalty situation.
A common heard opinion of product developers and managers in industry is that the scientific results are often of low usability and/or already known to them (Björk & Ottosson 2005). The commonly used outsider research perspective simply points to the fact that the research findings provided have already been experienced in industry when results are presented. In some cases, the result does not correspond to common praxis and experience. Thus, the application of the outsider perspective unfortunately means that researchers are one step or more behind the development in industry, and could only present results which are "state of the art". This must not be a wanted situation when governments put a lot of money in research activities aimed to strengthening the competitiveness in industry by developing new and effective tools and methods. To be close and to be present is crucial for researchers who want to be at least one step ahead of industry, which in turn requires more action oriented research in the field of product development.

1.2 Research from a technical point of view

Research on product development processes done by researchers with a technical or natural science background is often limited to pieces of the development process and mostly is of the type describing effects of using different tools – thus a narrative approach. The practical value of the narrative approach can be considerable. However, noticed in the academic society of product development processes is that the transfer of research findings to industry has shown to be slow and that the development of tools mostly is driven by commercial enterprises leaving to the researchers to test the different options.

1.3 A need for an innovative research approach

As is seen in figure 1, the most unpredictable factor in each of the circles is humans being involved in the development process. The complexity of a person mainly comes from his/her mood, interest & motivation (see figure 3). These three factors will work as reflection & selection filters letting more or less new information add to the knowledge and experience the person already has. The mood, interest & motivation can change considerably with time – and in an unpredictable way - which makes traditional research problematic to be applied on ongoing processes. This as the researcher not being present over a longer period of time can get an impression of a person that is not representative for a more normal situation.
In addition, every development process is unique, which means that theories cannot be proved to be true or false in a traditional fashion (Andreasen 2003), and only when they are eventually used as methods can their productivity be evaluated. These two characteristics of product development processes make research on them special (see e.g. Blessing et al 1998, Blessing 2003, Cantamessa 2003, Bender 2003, Holmdahl 2006) and gradually the awareness is growing in the technical research society that traditional research methods are not designed to be used on complex, non-repeatable processes. Thus, in contradiction to research on complicated systems as machines for which the interfaces between their different parts do not change over time, complex systems can not be broken down in small stable pieces that separately can be studied and assembled to a total system.

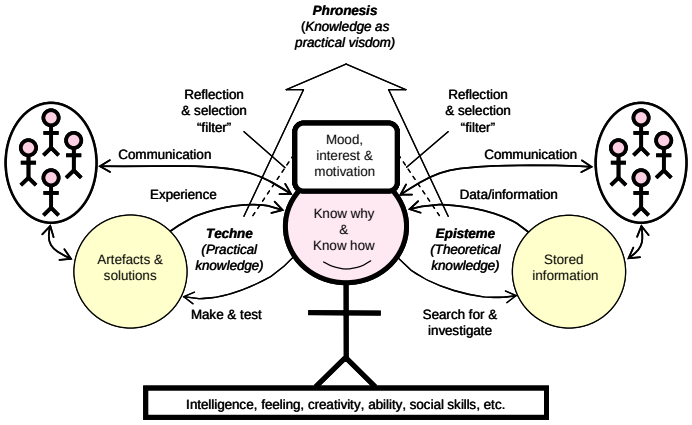

Figure 3. The individual knowledge (know-why and know-how) is generated by many factors of which some important ones are shown in the figure. Stored information is here recorded information. Artefacts are models, prototypes, manufactured products, etc. (Ottosson 2003-b)

A conclusion of this might be that researchers having focus on product development today do not manage to grasp what really happens on a daily basis in a development project if and when they have an outsider position for their investigations. The quantitative view is also limiting as theory on how to best develop (new) products is improved only by comparing findings from one project with findings from other projects having been studied in a qualitative way. Thus, for the researcher to be able to understand what happens in a development project and its complex nature, to get the opportunity to reflect upon it, to be able to contribute to the knowledge of product development, and to be able to give sound recommendations on how to better develop products, we have found it necessary for the researchers to make qualitative studies having an insider position instead of making quantitative studies having an outsider position.

2. The ambitions of the authors

Our main reason for doing research on product development processes has been - and is – at the same time to extend the scientific knowledge and to improve the usability in methods and tools with the aim to produce improved products seen from several perspectives. Fulfilling such demands the researcher must try to understand, interpret, and portray the human experience and discourse in organized practises. To accomplish this we mainly have used and use an abductive approach.
In addition the authors have an interest and ambition to reduce the risks for failure especially when new products are to be developed and commercialized and to contribute to that the new products in a broader perspective help to increase quality of life for at least one individual without decreasing it for other individuals or affect the environment in a harmful way (Ottosson 1999).
To reduce commercial risks, short Time to Market is paramount especially for companies producing products for which product life cycles are short (Ottosson 1998). Other factors to reduce failure risks are cost efficient development, the development of user friendly solutions with good "soft" values, low logistic and production costs, and high commitment of the developers, just to mention some important influencing factors.

3. Background

Since 1985 the IPD methods (Ohlsson 1985 and Andreasen & Hein 1987) had been used on New PD student projects at Halmstad University in Sweden. In 1994, the author Ottosson as senior lecturer at the University noticed that the concepts of IPD led to long development time in the student projects compared to what he was used to from his industrial experiences in companies as ITT Flygt AB, SKF AB and Handiquip AB in Sweden. He therefore initiated a new approach by mixing parts from the IPD theories and parts from his former industrial experiences and developed DPD (Dynamic Product

Development). Later comparing studies of student groups performing development according to IPD principles on the one hand and according to the DPD principles on the other gave the impression that the DPD principles meant advantages in new product development for which time to market is extremely important. From 1997 therefore the DPD has been used as development method in the NPD projects at the Innovation managment BSc programme. The DPD has developed to be a book (Ottosson 1999).
In 1999 the conceptual relation between action research and *quantum physics* was also identified (Ottosson 2001). However, it was also found that dynamic management needed not only quantum physics as philosophical model as some authors had proposed (e.g. Zohar 1997, Kaku 1998, Wheatley 1999) but also two other theories, *chaos theory* and *complexity theory*. Figure 4 shows the conceptual background for the Classic Theory and the Dynamic Theory used in management and to some extent also the management of research activities.

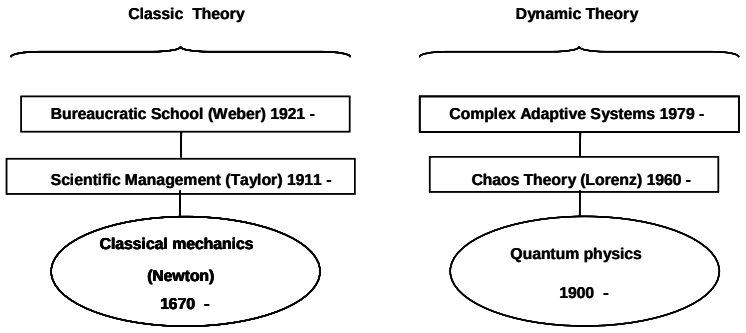

Figure 4. The conceptual background for the Classic Theory and the Dynamic Theory used in management including management of research activities. The figure also tells when research started or was published for the different principles

1996 a discussion started between authors Ottosson and Vajna on how to improve the development process and on how to develop research methods on product development processes. From 2000, the discussions between the two authors became a closer cooperation and from 2004 author Ottosson is guest professor at the chair of author Vajna at Otto-von-Guericke University. In 2003 the first PhD thesis on Insider Action Research was defended by author Björk at the chair (Björk 2003). It is expected that in 2006 the second PhD thesis on the topic by author Holmdahl will be defended (Holmdahl 2006).

4. Research considerations

Research on compex systems can be devided in the three parts basic, applied, and clinical (e.g. Friedman 2000, p18) with overlapping interfaces between the three types of research activities. *Basic research* means to search for general principles. *Applied research* means adapting general findings to classes of problems. *Clinical research* is related to specific cases but is not a well found term for product development. Romme's (2004) term design is maybe better as it points on a creative side of reality – taking steps forward into the unknown. Thus, research on product development includes development, testing and evaluation to discover or to contribute to a body of general knowledge and to set the findings in relation to earlier published findings and theories.
Ideally, research on complex social systems mainly is a process of interaction between practice and theory. However, when researchers become excluded from the practical use of theories, they will just get fragmented information on how well the theories work and what needs to be changed in the theories to be better adapted for the practitioners. In learning from our research activities and reflecting on outcomes in an effort to find explanations that agree with the relevant theory, we can ultimately contribute new knowledge to existing theories, thereby strengthening them. Occasionally we can also find that existing theories are quite counter productive in their intended area of application

– which was partly the reason why the development of DPD started out of the aim to improve the IPD theories.
Theory in general can be regarded as "a set of well-developed concepts related through statements of relationship, which together constitute an integrated framework that can be used to explain or predict phenomena." (Strauss & Corbin 1998, p 15). To develop a "good" theory on how to develop new products and innovations – to develop a development method – will not work as such processes are complex meaning that they are situation dependent, time dependent, and dependent on the individuals involved, etc. However, a "good" product/business development method can be developed based on studies on reality from an insider position.
Acting from inside an organisation means performing *qualitative research* which is contextual and often unsystematic as in reality things happen in an unplanned way. Its counterpart - *quantitative research* - is systematic but often un-contextual (Scheff & Starrin 1996). In principle, qualitative research does not accept the traditional positivistic view of separating reality into subjects and objects. Instead the importance of access to the subjective reality of everyday life – or reality as experienced by the individual - is emphasised (Scheff & Starrin 1996). As knowledge of development processes build on contextual knowledge, a qualitative research approach is important as main research method for the analysis of empirical studies. This implies also the use of different research methods including quantitative studies. In principle quantitative research can be used to screen areas while qualitative research is needed to get a deeper knowledge of studied phenomena. During and after the development quantitative studies are often used to focus on some topics, e.g. the perception of a design in a chosen group of people.
The quantitative research approach often starts with a hypothesis on some theory or a previous statement. Qualitative research, in general starts out with a more open research question. The initial broad/vague research question then gradually develops and can with time be broken up into more specific questions. The benefit of such an approach is that the research questions, the experiences and the results are compatible with each other. The research questions become increasingly relevant as the researcher attains a deeper knowledge of the research field during the process. She/he can thereby gradually formulate more relevant questions.
When a qualitative approach is used the researcher will get a mass of information that she/he has to deal with. To pick out what to tell others from all information gained is difficult. The recorded material alone from an insider action research as observed at Volvo Cars during one year performed by Bragd (2002) amounted e.g. to over 400 hours. Also the use of fragmented citations, which is accepted and commonly used by action researchers, is by narrative theorists (e.g. Riessman 1993) regarded as problematic in that it destroys the narrative that is of paramount importance for understanding all the small pieces that build up reality in a holistic way. Author Björk (2003) gave two detailed examples of how limited information is that such a technique brings to the total information and understanding of a development project. The narrative approach simply showed to give a much better total understanding of the total process and pieces of it. Thus a narrative description of research done from an insider position over a longer period of time is of paramount interest when product development methods are investigated.
Using a narrative approach necessitates a somewhat different way of presenting the findings than the traditional research does. In that case the quality requirements for public presentation are that the knowledge is communicable, relevant, and trustworthy in terms of validity, credibility, and reliability.

5. Qualitative research aspects

Research can be made as prospective studies in real time or as retrospective studies in past time as two opposing possibilities. For studies of ongoing processes as innovation processes often the two methods are used together e.g. so that 80 % of the studies are prospective and 20 % are retrospective.
When performing prospective studies, three unique methods can be distinguished. They are to participate in a process, to make experiments and to make tests. Experiments and tests are often the same thing. When performing retrospective studies, one unique method can be distinguished and that is to make archival studies, i.e. to make studies in/on historical material (artefacts, written material, photos, sketches, etc.). For both prospective and retrospective studies common methods are to make

simulations, to observe, to make dialogues, to make inquires and to make interviews. The different possibilities are shown in figure 5. The figure also shows that the researcher can choose to mainly be inside the object studied or mainly be outside the object.

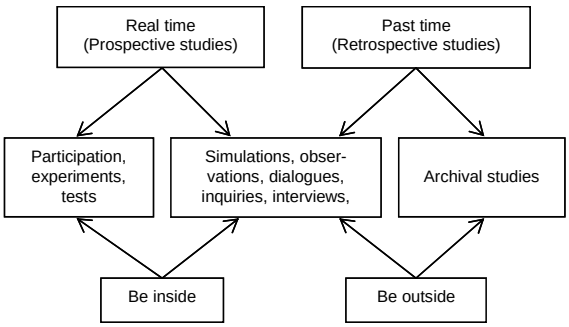

Figure 5. Research can be done as prospective studies and retrospective studies. Dependent on which track the researcher chooses to use different research methods can be used as is shown (Ottosson & Björk 2004)

According to our experiences, own use and own participation means that the reliability gets higher than if the researcher chooses other methods shown in the two right boxes on the middle row of figure 5. This as the information is first hand information without interpretation errors. How in principle reliability due to our experiences is dependent of method used is shown in figure 6. In principle, a qualitative treatment is used to the left in the figure while quantitative treatment is dominant to the right in the figure. This as statistical methods cannot be used on single qualitative studies while the reversed situation exists e.g. for inquiries.

According to classical theories, scientific knowledge should highlight the causes of events in our world. However, events are in complex systems difficult to find as the origin of changes initially are more or less invisible/noticeable (see e.g. Collins 2001 p 169). In addition, the methods used to obtain this knowledge are dependent on the formulation of the researcher's questions and perception of reality (Svensson & Starrin 1996) and methods/tools used. Further, the researcher's perception of reality has a decisive effect on his or her perception of human behaviour. This in turn strongly influences the scientific perception that is developed and the methods used to obtain scientific knowledge in a field like product development.

We must also bear in mind that quantum physics has taught us that we – the observers of reality - are, at the same time, the participants of reality. In other words, 'observation' is not a passive noun and 'to observe' is not a passive verb. However, our classical Western upbringing has preconditioned us to think objectively; to see the world as pre-existent (Wolf 1989, p146). According to modern physics, reality is constructed from your thoughts of reality, which means that reality is relative and not absolute, as everybody will have their own view of reality. According to this approach, objectivity does not exist in reality although a majority can have an equal picture of the same matter. Thus, giving up the limitation of the strong positivist view of objectivity in research opens up for performing Action Research, which means that the researcher is inside the ongoing process she/he is studying (inductive approach), has taken part in a process (deductive approach) or has been in a process and still is part of it of it (abductive approach) (see figure 7). When the researchers use the inductive approach they need to'step out of' the studied project now and then for reflections. Having a scientific environment to share the experiences in is of great help for reflection.

Performing Action Research (AR) means to be inside the studied process (see figure 8). However, AR can be performed in three ways. One can be an observer, a team member or the project leader/manager. Anyone can in principle be an observer while few researchers can in principle be team members in industrial processes. Fewer can be project leaders or managers. (Of natural reasons, also team members and project leaders perform observations. In addition, they perform traditional studies when studying other processes or competitors, etc.).

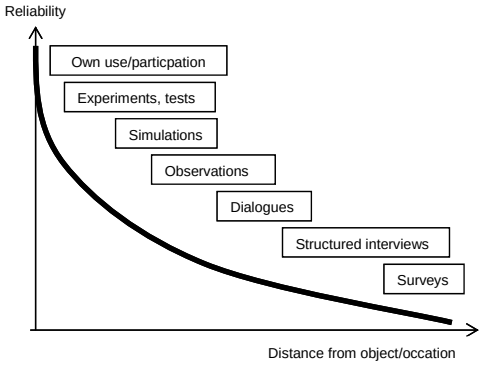

Figure 6. The distance from the studied object depending on probing method used influences the reliability of the information acknowledged (Ottosson1999). To the left in the figure qualitative treatment is used while quantitative treatment is used more and more on the behalf of qualitative treatment when methods to the right in the figure are used

Some advantages with IAR the authors have found in their IAR activities not possible to get with "hard" research approaches (e.g. questionnaire-based surveys) are:

- A minimum risk of loss of valuable information/data due to forgetfulness or incorrect reconstruction. When reconstruction of past events is made, there are risks of misunderstandings. The researcher has no opportunity to consider the circumstances outside or inside the studied process that may have influenced the result.
- First hand information eliminates the influence from other people's understanding of the situation and their ways of expressing it.
- Opportunities exist to rapidly make corrections in interview manuals or to clear out misunderstandings between the questioneers and the respondents.

The authors have also found that to be able to get most information from an ongoing project the researcher has to act as project leader. Three big advantages being project leader/manager instead of being a team member are:

- The experience and knowledge gained from participating in the studied process gives the researcher unique possibilities to lead a later implementation of the research findings. The organisation feels familiar and confident with the ongoing process and the person leading it.
- The result can be useful for practitioners; this is sadly lacking in current research findings when classical research methodology is used.
- The user satisfaction of the products can increase when a holistic view is accepted as mediating tool in research and in product development in practice.

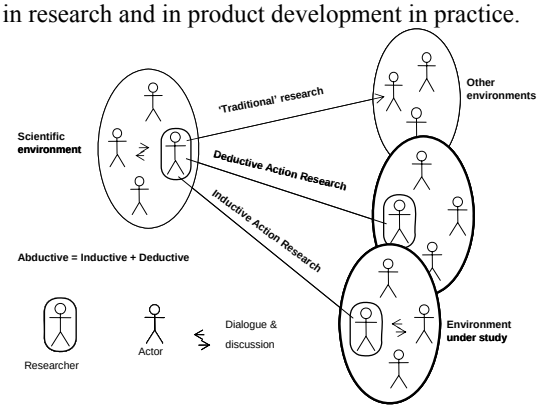

Figure 7. Illustration on relations involved in an action research approach, which can be done with an inductive, deductive and abductive approach

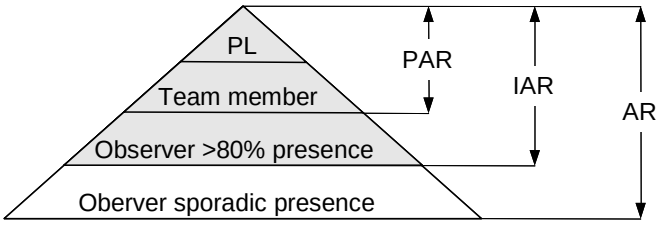

Figure 8. The figure illustrates the relations between Action Research - AR, Insider Action Research - IAR and Participation Action Research - PAR. It is the time spent in the system that qualifies an observer as action researcher or insider action researcher. Taking part in the work means that the researcher will be a participation action researcher. (PL = Project Leader)

Conducting IAR means that the information flow is massive and that it is difficult to select important pieces. Also the big steps show in general – due to chaos theory – to have started with small invisible changes which grow exponentially, suddenly becoming visible as a big change after some time. Being present most of the time in a development process means also that the small changes, which appear unevenly distributed in time, can be grasped (see figure 9).

From a traditional reliability aspect, in order to be reliable the comparison between two methods should be carried out by the same developers using the same method and developing the same product twice. However, when developing the first edition of the product, the developers will learn what to do, which will have effects on the development of edition two. As "de-programming" is impossible the same developers simply can not compare two methods with trustworthy conclusions as a lot of uncontrollable aspects may influence the outcome. Neither would using different developers give a comparative situation as the individuals have different backgrounds, competence, capacity, etc.

To overcome that problem, comparing performance has been used and discussed in several research studies (e.g. Wallace & Ahmed 2003, Tversky et.al. 2003, Ahmed & Wallace 2004). In these studies comparisons have been done between *novices* and *experts* as well as comparing studies of novices (e.g. Badke-Schraub & Stempfle 2003). Comparing studies of experts has also been done (e.g. Badke-Schraub & Frankenberger 1999). To give most reliable results for comparing tests of different performances and tools we argue for using novice students of roughly the same age and roughly the same grades before entering the university, although this approach is not problem free (see e.g. Klein 1999). If such studies are performed at the same time, the differences can be more observable than if the studies are made separated in time. That method was used to compare the effects of IPD and DPD early in the development of DPD 1994-1995 at Halmstad University College.

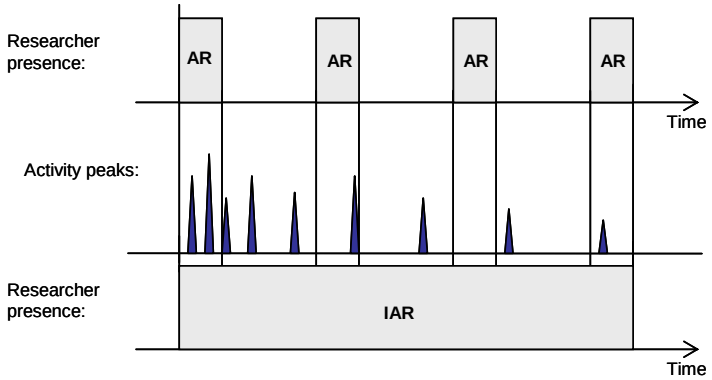

Figure 9. Activity peaks of different magnitudes occur unevenly distributed. To catch them it is not enough to be present now and then, as is common for Action Research (AR). The researcher needs to be present most of the time - doing IAR - to get a good understanding of the development process (Björk 2003)

6. Participation action research

As pointed out, principally there is a difference between conducting IAR as researcher/observer and being part of the development as manager/leader or team member – being researcher/practitioner. We therefore have chosen to call being researcher/practitioner making IAR for doing Participation Action Research (PAR) (Ottosson 2003). Doing PAR means in addition to IAR to take part in the development activities and to perform experiments on development activities.

Making PAR the *duality issues*, *pre-understanding* and *political role* are different from making IAR as observer for which these three parts of the daily work do not influence the outcome of the research work.

In principle the observer does not need to be accepted by the people in the studied process although practitioners can be frustrated over having someone present who does not take part in the everyday work (Bragd 2002). Thus, duality issues should not be a big problem for observers being present most of the time in a development project while it can be a problem being part of a team or being project leader of a team. The project leader, but also the team members, will have a political role during the work done, while an observer will not have a political role while making the observations. However observers can play a large political role when the report is being made public.

This political role of a researcher when publishing the findings was demonstrated when the observer Bragd revealed that the official position of Volvo was to put environmental questions as very important in the development work while it in practise was not regarded at all (Bragd 2002). When mass media found out that, Volvo representatives had to explain that there was a misinterpretation based e.g. on that the researcher did not have enough pre-understanding of how things were done at Volvo Cars. In turn that situation pointed on a problem giving the researcher the total right to publish whatever findings as they can be disadvantageous for the company studied. In most countries researchers are not allowed to get into a company on totally free conditions. Sweden, Norway, Denmark and Finland seems to be a rather unique exception from that rule.

Performing PAR means a loyalty problem for the researcher, why it is extremely important that the researcher carefully explains her/his loyalty situation in the reports given (Björk & Ottosson 2005). Preunderstanding makes the work easier but within a few weeks normally anyone with relevant knowledge and social skills will have accumulated enough information to be an accepted member in a team. The political dimension is very important in every development project and again that will bring loyalty problems to the researcher. Revealing the game behind the scenes can cause big problems to the people taking part in the game and as people are more vulnerable than organisations the researcher with much inside information has to judge carefully how and what to present in public.

7. Conclusions

The simple view of science - when a common belief was that only one best method or solution was possible to find, when mathematical logics ruled the world, and when everything in principle could be simulated and planned to give wanted results - is gradually being broken down. Unplanned situations, large and small, occur more quickly. Society in general and industry in particular, therefore, will put pressure on the researchers to produce useful findings and conclusions worthy of trust that strengthens the industrial competitiveness and which contributes to increased quality of life. For the findings to be accepted, understood and used the method of communication used, the pragmatic writing, and the actuality of the findings is crucial. The outsider approach means that the researchers will be one step behind the development in industry.

To increase usability, to facilitate research conclusions and to increase the trustworthiness of the findings we have found it important that the researchers conduct Insider Action Research and especially Participation Action Research and that a lot of attention is paid to validity, reliability, credibility and usability. Especially the loyalty of the researcher must be treated in the reports, which also needs to be treated in all types of scientific reports as the researcher always has the right to choose what to present and how to present it.

The political dimension is very important in every development project which can bring loyalty problems to the researcher. Revealing the game behind the scenes can cause big problems to the

people taking part in the game and as people are more vulnerable than organisations the researcher with much inside information has to judge carefully how and what to present in public.
One problem for the researcher that has to be worked further on is that when she/he is doing IAR studies she/is is within an excess of data flow difficult to handle.

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