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ASPECTS ON USABILITY AND THE TRUST IN RESEARCH RESULTS ON COMPLEX SYSTEMS

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Abstract: *Product development processes are unique and complex. Quantitative research methods are limited in use in such processes, as their methodology focuses on generalisation of findings and not on the understanding how and why certain events occur. To reach a deep understanding, therefore, the main research approach needs to be qualitative, especially as product development on a detail level has to be dynamic in order to take advantage of the unplanned changes and opportunities that occur.*
To grasp what really happens on a daily basis in a development project, to be able to reflect upon it and to understand the complex nature of the process, it has shown to be beneficial to perform action research. Researchers who are present most of the time inside the studied project, perform so called Insider Action Research (IAR). IAR can be performed either as project leader, team member or observer.
To improve the opportunities for implementation of research findings, which is an important issue, and to secure trustworthiness in presented research findings, the results have to be pragmatic and communicative validated. A presentation of the researcher's experience and pre-knowledge from the actual field is valuable for the evaluation of the credibility. As the research situations are impossible to repeat under equal circumstances for product development processes in general and for innovation processes in particular, reliability in terms of provable data filed in diaries, fax and e-mail communication have to be saved to be available for scientific judgement if required.

1. INTRODUCTION

1.1 Background

Complex processes change with time and often in an unplanned or unforeseen manner. Traditional research methods are not designed to be used on complex, not repeatable processes, which is why there is a need for other methods for studying such processes [11, 20]. The big challenge is to find methods for research that are designed to describe the complexity without reducing reality to small areas suitable for traditional research methods [2].

So far, research in the field of product development show that a lot of focus has been placed on the development of tools and methods, in particular computer based tools and methods. Researchers and toolmakers are confronted by the challenge of creating a well-structured framework grounded in a proper understanding, something which still remains to be achieved [1].

In traditional research, objectivity and repeatability are important variables. However, according to theories from quantum physics, researchers always influence the studied objects or the measuring process, which is why objectivity is difficult in this context [e.g. 10]. In addition repeatability is even more difficult to handle in processes where humans interfere and where important unplanned and unforeseen events occur.

Validation of research findings on product development processes may not be possible to measure because of available research time (it may be years before the effects of research influences an aspect such as lead time) or because the goal is formulated at too high a level [20]. A large number of interrelated factors may also have influenced the goal/process, not just the one that has been addressed [2].

Within industry it is commonly recognised that traditional theories and instruction manuals on how to perform product development unfortunately have very little relevance to practical work [e.g. 3, p 56]. One reason for this is that the research methods used are often poorly related to the context and complexity of product development processes. Another reason is that calculations and simulations only represent simplifications of stable/ideal situations, which is why predictions do not take the unpredictable and chaotic aspects of innovative development projects into account.

In addition, product development is very much a social activity in which communication plays an important role [18]. In projects, contact with others and communication between networks provide beneficial input. Although e.g. much effort has been devoted to developing computerized expert systems, product developers have shown to rely to a greater extent on personal contacts than on the information collected from expert systems [16], partly due to the fact that dialogue widens the scope of discussions.

1.2 Aim

The aim of this paper is to highlight the problems with today's usage of classical research methods on complex processes and to discuss qualitative methods as an alternative to achieve more useful and trustworthy results. A proposition on "guide lines" for what issues needed to be treated in scientific reports performing qualitative research is presented.

2. THE RESEARCH BACKGROUND

Our interest for research on product development processes has its origin in several years of experience participating in industrial product development projects mainly in Sweden (ITT Flygt AB, SKF AB, Nordinvent AB, Careva Systems AB, Camp Scandinavia AB, Handiquip AB, Access Industries, Prosolvia AB, Frontec AB). To achieve a better understanding of the complex processes of new product development, to improve the models and to increase the usability of them, research with a new approach became necessary. In addition, the overall interest to increase the usability of the models for the practitioners, was in accordance with the action research methodology that was developed more than 50 years ago by Levin [21].

According to Levin's philosophy, an action research project is not finished until it is implemented in reality [21]. Thus, to define a problem or a need is just the first step in the study of a project or a process. The second step, according to him, is to find a solution which could improve the actual situation. A third step is to see that it gets implemented. The transfer of research findings to industry has been shown to be a really hard issue which, among others, has been documented by several researchers [e.g. 1, 22, 23].

The frame of reference for this paper is Theories of Action Research, for which more than 50 years of publication exist, and Insider Action Research, which is a rather new direction of Action Research [2, 27].

The background to this paper is to a large extent a spin-off of the research and the development of the so called Dynamic Product Development (DPD) methodology [28, 29]. Initially that development started in 1994 at Halmstad University with the aim of improving the Integrated Product Development method being used at that time [30]. In 1996 the Centre for Product Development Research (CPDR) had also been established to do research in the field of product development.

From the start of CPDR a close relationship was established with the Centre for Work Development Research (CAU), which was then another research centre at Halmstad University. The researchers at CAU performed Action Research projects e.g. in cooperation with several industrial enterprises. Their knowledge and experience from the sociological field inspired the research at CPDR as most researchers at CPDR came from the natural sciences society. Fruitful discussions with other scientists performing action research, e.g. [17] at the Royal Institute of Technology in Sweden, gave important inputs and stimulated the interest for further action research at CPDR.

A strong relation between action research and quantum mechanics, but also the connections to modern theories such as chaos theory and complexity theory was found [28]. A closer contact was also established with professor Vajna at Otto-

von-Guericke University in Germany in 1998. Figure 1 shows schematically the background and influences to the development of Insider Action Research.

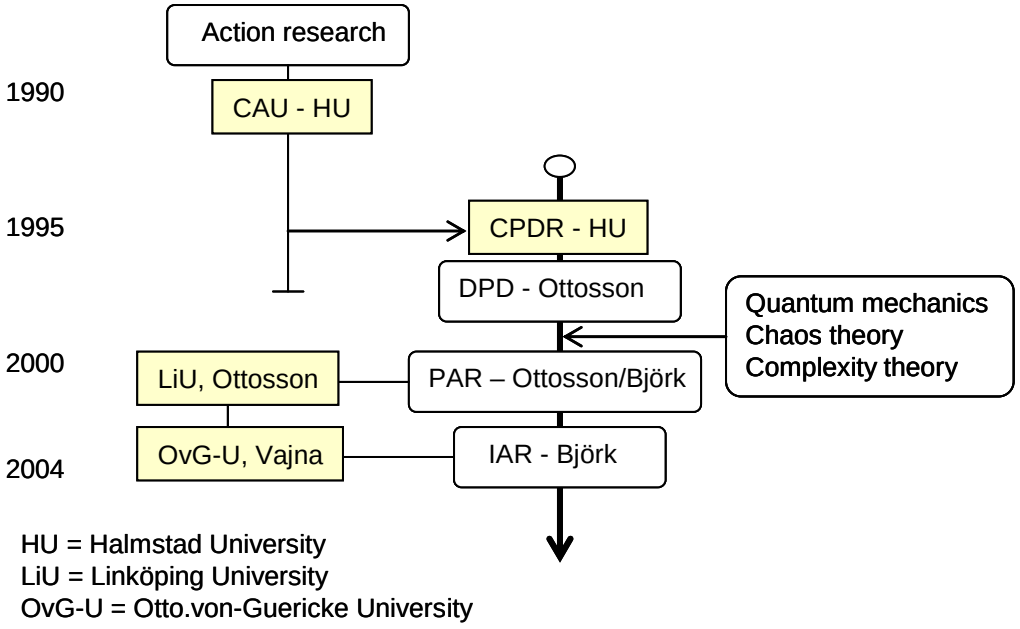

Fig. 1 *The development of IAR*

3. RESEARCH CONSIDERATIONS

Acting from inside an organisation means performing qualitative research, which is contextual and often unsystematic given that unplanned things tend to happen in real life. Its counterpart - quantitative research - is systematic but often un-contextual [12]. 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 [12]. As knowledge of development processes build on contextual knowledge, a qualitative research approach is important as the main research method for the analysis of empirical studies. That implies the use of different research methods including quantitative studies. Quantitative research can be used to screen areas while qualitative research is needed to get a deep knowledge. During and after the development quantitative studies are often used to focus on some topic, 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. In general, qualitative research 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 and can thereby formulate more relevant questions.

When a qualitative approach is used the researcher will get a mass of information that he/she has to deal with. To select the important parts from all the information gained can be difficult. Only the recorded material from an insider action research as observer at Volvo Cars during one year performed by Bragd [3] amounted e.g. to over 400 hours. Also the use of fragmented citations, which is accepted and commonly used by action researchers, is regarded by narrative theorists (e.g. 26] 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. In a PhD thesis [2] the author gave two detailed examples of how such a technique brings limited information to the totality of information and understanding of a development project. The narrative approach showed in that thesis 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.

The research on complex social systems is mainly a process of interaction between practise and theory where practise constitutes the basis for the creation of a theory (c.f. figure 2). The information will be fragmented if the researcher is cut out of the practical use of theories, and opportunities for improvements will, in such a case, be inhibited. As a result of qualitative research and the effort to find explanations that agree with the relevant theory, new knowledge can be added to existing theories, thereby strengthening them or rejecting 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 as a result of the aim to improve the IPD theories). To be able to develop a "good" product/business development method it is necessary to study reality from an insider position although classical objectivity gets lost when it becomes part of the process. 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." [13, p 15].

Using IAR with a narrative approach necessitates a somewhat different way of presenting the findings then for traditional research. In that case quality requirements for public presentation are that the knowledge is communicable, relevant, and trustworthy in terms of validity, credibility, and reliability. The presentation below should be seen as a suggestion on how to handle trustworthiness in qualitative research findings.

The qualitative approach (the right column in figure 2) will be treated here, to a certain degree, as a basis for further discussions regarding research on complex systems.

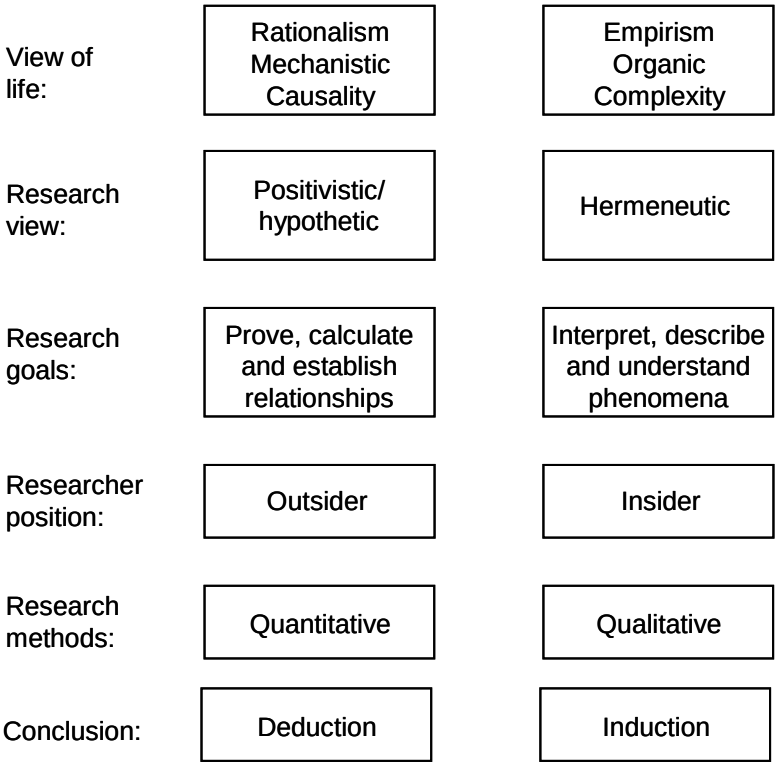

Fig. 2: *An illustration of comparative research views*

5. QUALITATIVE RESEARCH ASPECTS

As product development processes are complex with human beings involved behaving more or less rational, a hermeneutic approach (the right column in figure 2) seems to be more appropriate when performing research e.g. on product development processes. The hermeneutic approach has an organic view that tries to explain/understand specific behavioural patterns. Knowledge for that approach is mainly built up from reflections on previous experience and not from one single experience that is multiplied.

Performing IAR generates a massive information flow from which it is difficult to select important pieces of information. Also the radical steps in development show in general – due to chaos theory

– to have started with small invisible changes which grow exponentially to suddenly become visible, after some time, as a radical change. Being present most

of the time in a development process also means that the incremental changes, which appear unevenly distributed in time, can be grasped (see figure 3).

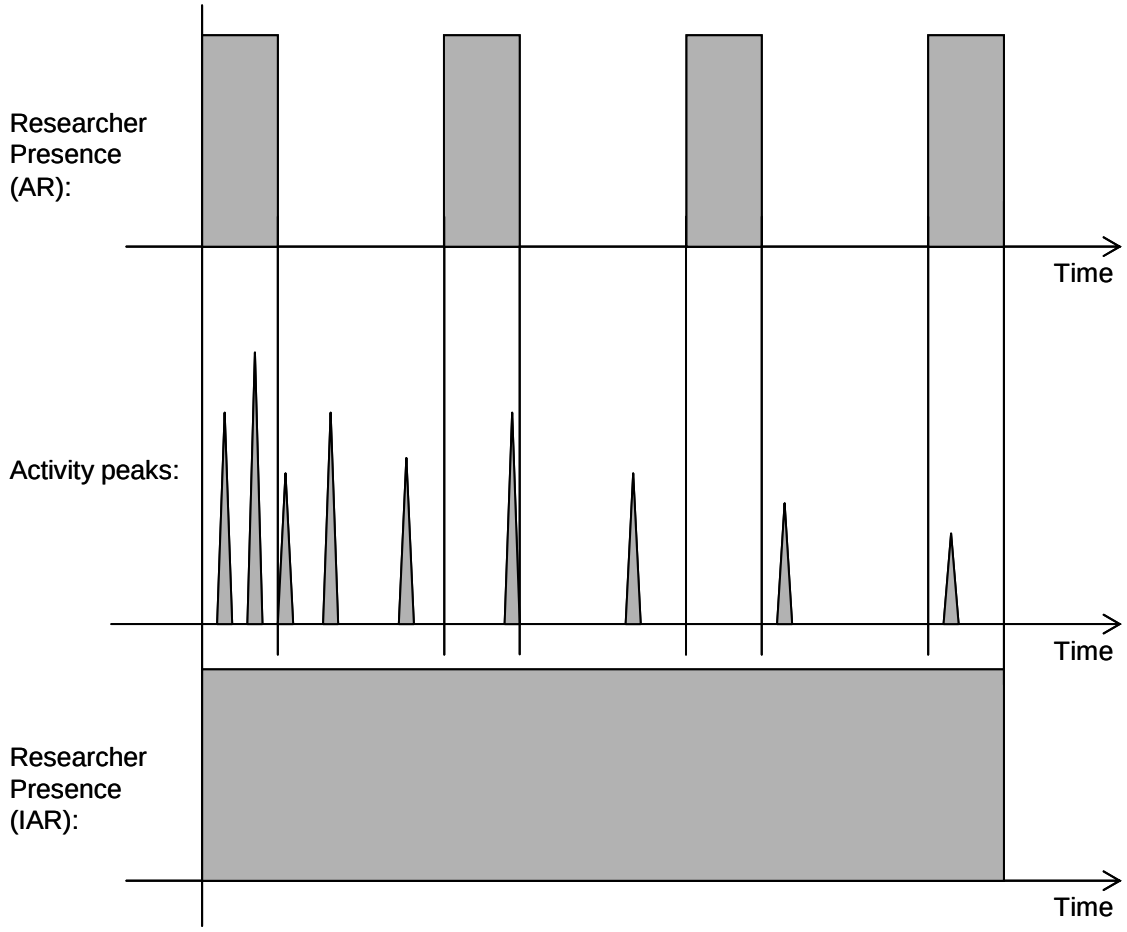

Fig. 3: *Activity peaks of different magnitude occurs unevenly distributed in reality, which is why the researcher needs to be present most of the time to get a good understanding of the development process [2].*

From a traditional reliability aspect the comparison between two methods should be carried out by the same developers using the same method twice and developing the same product in order to be reliable. However when developing the first edition of the product, the developers will learn what to do which will affect the development of edition 2. 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.

Comparing performance has been used and discussed in several research studies [e.g. 16, page 19]. In these studies comparisons between *novices* and *experts* have been described as well as comparing studies of novices [e.g. 24]. Comparing studies of experts has also been done [e.g. 25]. To overcome the problem we argue in favour of the use of novice students of roughly the same age and roughly the same grades before entering the university to give most reliable results for comparing tests of different performances and tools. If such studies are performed at the same time, the differences can be more observable than if the studies are made separated in time.

As every development process is unique and contains many interacting factors (see figure 4), the more tests and observations there are with which to compare the findings, the more usable the development methods can be.

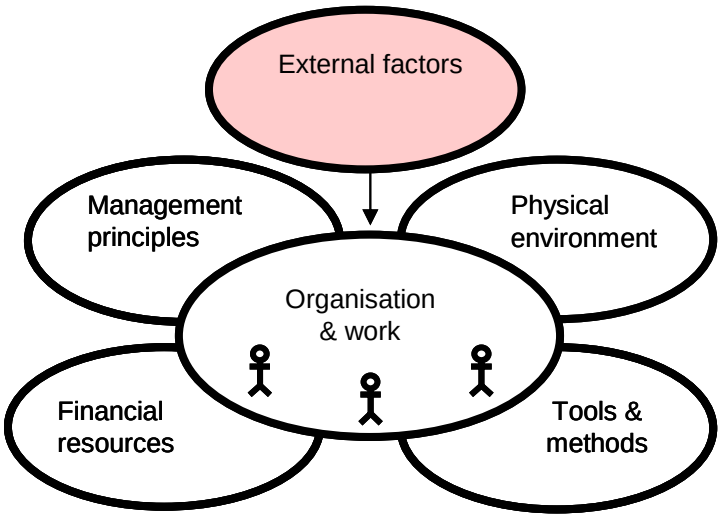

Fig. 4: *Several time dependent factors interact in product and process development [8]*

6. PRESENTING QUALITATIVE RESEARCH

Every scientific journal and every scientific conference board presents rules for the design of a scientific article/paper. All have in common that the articles/papers should incorporate the following items:

- Abstract
- Keywords
- Introduction, (background, purpose)
- The design of the study and the methods used
- Results/findings and data analysis
- Conclusions
- References to other research done

For the readers to be able to judge the trustworthiness of the results and quality of analysis and conclusions, *validity*, *reliability* and *credibility* need to be dealt with. We argue that when the research is based on qualitative research *usability* should also be dealt with.

6.1 Validity

Validity, from the classical point of view, concerns the relation between the results of the study and the formulated research question – which is a positivistic tradition. So, then, is the research design set up and carried out in such a way that the results achieved are answers to the research questions? In other words, can the research method supply the researcher with information that answers the research questions asked? Depending on whether the questions asked are relevant, that will decide if the case is of limited interest or not.
Validity in research is, from the classical point of view, not relevant for qualitative research as the research questions are initially vague (c.f. figure 2). The research goals in that case are to interpret, describe and understand phenomena, which is different to the situation for quantitative research for which the research goal is to prove, calculate and establish relationships. Therefore validity from the classical perspective is difficult to handle in qualitative research. However we can treat pragmatic validity and communicative validity for qualitative research, which also should be done for qualitative research presentations [6].

[*Pragmatic validity* means, according to Kvale [6], that the researcher must argue and convince the reader of the analysis and usability of the results. If the conclusions sound reasonable they become trustworthy. *Communicative validity* means that the interpretations made by the researcher are communicated to and discussed with individuals involved in and connected to the research. How that is done should be reported by the researcher in his/her documentation.]

6.2 Reliability

Reliability concerns the quality of the research results. Something is reliable if it is worthy of reliance and trust. Questions to ask are if the claims are well grounded and if it is possible to follow the argumentation.

In quantitative research the term reliability also means "repeatability" or "consistency". Repeated measurement of a fixed object that gives the same result indicates a high level of reliability in terms of traditional science.

In the qualitative tradition reliability must be evident from the actual context. For example, if a respondent is asked the same questions on two separate occasions, the answers given can be totally different

due to contextual variations although they will still be valid. On the other hand, reliability can be high if the answers are identical, although they can be totally invalid if the questions do not measure what they were intended to measure.

The following aspects contribute to the perceived reliability of the presented results of a research work:

- *Triangulation:* The use of several data sources such as dialogues, interviews, observations, documentation, personal notes, and communication (e.g. letters, e-mails, fax, etc.).
- *Contributions – peer reviewed:* If the findings have been published in well reputed journals and to some extent at scientific conferences with peer reviewed contributions, that should be a sign of increased reliability.
- *Contributions – not peer reviewed:* Presentations of the projects and results at seminars, workshops, trade shows and public lectures should also contribute to the reliability as the researcher in such cases has to argue for the findings and re-evaluate the findings when new questions and comments are presented to him/her.
- *Industrial grounding:* If the experiments have been done in an industrial environment or set-up, that should in general be proof of higher reliability than if the experiments have been done solely in other environments. Presentations, demonstrations and follow-up discussions at other companies, for local authorities, etc. increase the scrutinizing reliability of the findings. Sponsorship from local authorities for the development projects as well as financial support from different sources can be a sign of acceptance although at a much lower degree than for direct industrial sponsorship.
- *Presence over time:* Presence over a longer time period is important for the generation of knowledge.
- *Making pre-knowledge explicit:* Without knowing the background of the researcher the reader can not judge the reliability of the work.
- *Documentation:* Which documentation methods have been used? (Examples are: note books, photos, recordings, video films and other documentation.) How can other researchers get access to the documentation?

6.3 Credibility

Credibility may be understood as an assurance that evidence exists for the results obtained and that reasonable interpretations have been made [14]. The researcher can deal with credibility in the following way:

- *The researcher's contribution:* Description of the theoretical and practical outcome of the result of the work.
- *Separation of roles:* How the researcher has separated her/his time when the research took place.
- *Reporting of positive and negative results*: The researcher has to report both positive and negative results.
- *Bias:* The researcher has to declare pre-knowledge in more detail than in a CV, as bias is formed by the influence of previous experiences and environments that one has encountered.
- *Loyalty:* Every researcher has personal loyalties e.g. towards ideas, theories, religious beliefs, laws, rules, policies, products, organisations, individuals, him/herself, places and nations. It is extremely important to explain different loyalty connections for the reader to judge the credibility of a research work.
- *Interpretations:* The interpretations of events, artefacts, etc. are of necessity the author's. The researcher has to show that he/she is aware that other interpretations and opinions exist especially at detail level and are related to individual backgrounds, aims, etc.
- *Authenticity:* Authenticity is important for convincing the reader that the researcher really participated in fieldwork and has understood "what is going on here" [4]. The text should demonstrate that the researcher is familiar with the jargon and the study population [15].
- *Plausibility:* Concerns convincing the reader that the research contributes to the body of knowledge in the research area [4]. It is a matter of getting the reader "on your side: I will go along with you, set aside my doubts" [15].
- *Criticality (Critical evaluation):* This concerns the ability of the text to provoke the reader to reflect upon his/her taken-for-granted assumptions of the research in the field: "By God, I never thought of that!" [4]. For a development project the author(s) have to report the development of the projects as openly and honestly as possible.

6.4 Usability

According to ISO (ISO DIS 9241-11) *usability* is the effectiveness, efficiency and satisfaction with which specific users can achieve specified/particular goals in particular environments.

Performing action research has as its goal to extend scientific knowledge and 'to help the practitioners' [21]. As the outcome of product development, measured e.g. in usability, user satisfaction and profit, is dependent to a high degree on the overall and complex reality, the research presented needs to focus on and discuss the usability of the findings for the practitioners.

The following variables can be recommended for scientific research presentations as a way to contribute to the support of the implementation of research findings:

- *Effectiveness*: Is the product development method or tool proposed by the researchers effective for reaching the goal of the practitioner? Is it possible to implement the findings into real product development projects? What is required in order to make that happen (e.g. education needs, training needs, expert needs, tools acquisition, organisational change, etc)?
- *Efficiency:* Is the method or tool proposed efficient to use? Is it tricky to use? Is it time- resource intensive?
- *Satisfaction:* Will the users find the result more pleasant to use than what they experienced before the implementation? Will the users feel that the outcome is more efficient? Will the use of the new method or tool contribute to a better economical result for the company? Will it reduce failure risks? Are there any environmental risks?
- *Implementation:* Which strategies shall be used most efficiently to implement the results of the research? Which critical points could there be? How to measure hard and soft values?

7. CONCLUSIONS

The scientific society has always been discussing methodological issues and guidelines have been created as to which methods and approaches can be evaluated as "good research". However, as times have changed and new areas of interest for the society to develop occur, as new technologies are invented and knowledge in most areas has increased dramatically fast, the research society ideally should be in front of developments and not behind of them. The society in general should put demands on the researchers to present results that are useful and increase the quality of life for people in general, which demands the use of qualitative research methods, and especially AR with a narrative presentation approach.

The Platonian belief that only one single method or solution is needed has gradually been eroded as unplanned situations occur with shorter intervals of time both in micro amd macro situations. This necessitates a presence of the researcher most of the time (IAR) as observer, team member or project leader.

To increase the usefulness and usage of research findings and to increase the trustfulness of the results and conclusions, it is important that the researchers pay a lot of attention not only to validity, reliability, and credibility but also to usability. When research is financed through private industry rather than through the State, there are higher and more immediate demands on usability and trustworthiness.

In section 6 we have given checkpoints on what to address in order to satisfy demands on the usefulness and trust of the findings.

REFERENCES

[1] Andreasen, M.M.: *Improving Design Methods' Usability by a Mindset Approach,* in Lindemann, U. (ed.): *Human Behaviour in Design*, Springer Verlag (ISBN 3-540-40632-8), Germany, pages 209-218, 2003

[2] Björk, E.: *A contribution to Insider Action Research Applied on Development of Assistive Products,* PhD Thesis, Otto-von-Guericke-Universität, Magdeburg, Germany, 2003

[3] Bragd, A.: Knowing Management – An Ethnographic Study of Tinkering with a New Car, PhD thesis at School of Economics and Commercial Law at Göteborg University, Sweden, 2002

[4] Golden-Biddle, K. & Locke, K.: Appealing Work: an Investigation how Ethnographic texts Convince, Organization Science, Vol. 4, No 4, November, 1993

[6] Kvale, S.: Den kvalitativa forskningsintervjun (in Swedish), Studentlitteratur, Lund, Sweden, 1997

[7] Ottosson, S.: The Development and Research of the Dynamic Product Development – DPD Method, EDIProD Polen, 2004

[8] Ottosson, S.: *When time matters,* Key note speech, Tools & Methods in Competitive Engineering (TMCE004), Lausanne, April 13-17, 2004

[9] Ottosson, S.: *Participation Action Research – A Key to Improved Knowledge of Management,* Technovation - the International Journal of

Technological Innovation and Entrepreneurship, Vol 23, pages 87 – 94, 2003

[10] Ottosson, S.: *Dynamic Concept Development – A Key for Future Profitable Innovations and New Product Variants*, ICED 01, Glasgow, August 21-23, pages 331-338, 2001

[11] Blessing, L. Chakrabarti, A. & Wallace, K.: *An overview of Descriptive Studies in Relation to a General Design Research Methodology*, In Frankenberger, in Frankenberger, E., Badke-Schaub, P. & Bierkhofer, H. (eds.): *Designers – the Key to Successful Product Development*, Springer Verlag, London, 1998

[12] Scheff, T.J., & Starrin, B. : *Om delar, helheter och sociomorfologisk metod*, in Svensson, P-G.& Starrin, B.: *Kvalitativa studier i teori och praktik* (in Swedish), Studentlitteratur, Sweden, 1996

[13] Strauss, A.M.& Corbin, J.: *Basics of Qualitative Research*, Sage Publications, Newbury Park, 1990

[14] Svensson, P.-G.: *Förståelse, trovärdighet eller validitet?*, in Svensson & P-G. Starrin, B. (eds): *Kvalitativa studier i teori och praktik* (in Swedish), Studentlitteratur, Lund, Sweden, 1996

[15] Taxén, L.: *A Framework for Coordination of Complex Systems´Development*, PhD Thesis, Linköping University, Dep. of Computer and Information Science, Linköping, Sweden, 2003

[16] Wallace, K. Ahmed, S.: *How Engineering designers Obtain Information*, in Lindemann, U. (ed.): *Human Behaviour in Design*, Springer Verlag ISBN 3-540-40632-8), Germany, pages 184-194, 2003

[17] Westlander, G.: *Forskarroller i varianter av aktionsforskning - in Swedish*, Royal Institute of Technology, Stockholm, Sweden, 1993

[18] Westling, Gunnar.: *Balancing Innovation and Control*, PhD thesis at Stockholm School of Economics, Sweden, 2002

[19] Tversky, B., Suva, M., Agrawala, M., Heiser, J., Stolte, C., Hanrahan, P., Phan, D., Klingner, J., Marie-Paul, M, Lee, P., Haymaker, J.: *Sketches for Design and Design of Sketches*, in Lindemann, U. (ed.): *Human Behaviour in Design*, Springer Verlag (ISBN 3-540-40632-8), Germany, pages 79 – 86, 2003

[20] Blessing, L.: *Individual Thinking and Acting: Summary of Discussion*, in Lindemann, U. (ed.): *Human Behaviour in Design*, Springer Verlag (ISBN 3-540-40632-8), Germany, pages 97-104, 2003

[21] Lewin, K.: *Action Research and Minority Problems*, Journal of Social Issues, Vol. 2 (4), pages 34-46, 1946

[22] Norell, M.: *Competitive Industrial Product Development Processes – a Multidisciplinary Knowledge Area*, NordDesign '96, Helsinki University of Technology, Faculty of Mechanical Engineering, Espoo, Finland, 1996

[23] Arujo, C.S.: *Acquisition of Product Development Tools in Industry: - A Theoretical Contribution*, PhD Thesis, Technical University of Denmark, 2001

[24] Badke-Schraub, P. & Stempfle, J.: *Analysis of solution finding processes in design teams*, in Lindemann, U. (ed.): *Human Behaviour in Design*, Springer Verlag (ISBN 3-540-40632-8), Germany, pages 121 – 131, 2003

[25] Badke-Schraub, P. & Frankenberger, E.: *Analyses of design projects*, Desing Studies 20, pages 465 – 480, 1999

[26] Reissman Kohler, C.: *Narrative Analysis*. Qualitative Research Methods, Vol. 30, Newbury Park, Sage Publications, 1993

[27] Ottosson, S. and Björk, E.: *Participation Action Research – A Method to Improve Knowledge of Product Development and Innovation Management*, Tools and Methods in Competitive Engineering (TMCE-2000), Delft Technical University, Holland, April 2000

[28] Ottosson, S.: *Dynamisk Produktutveckling* (in Swedish), Tervix Förlag, Floda, Sweden, 1999

[29] Ottosson, S.: *Dynamic Product Development - DPD*, Technovation - the International Journal of Technological Innovation and Entrepreneurship, Vol 24, pages 179-186, 2004

[30] Olsson, F.: *Integrerad Produktutveckling (in Swedish)*, Mekanförbundet, Stockholm, Sweden, 1985