IDoESE 2006 PhD-study plan

Work title:	An empirical investigation of the costs, gains and prerequisites of agile software development.
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Abstract

The main focus of the study is agile software development (ASD) and related costs, gains and prerequisites. ASD is a relatively new field based on unclear definitions and concepts. A theoretical framework is shaping, however not still in place. The overall research question in the PhD-study is *What are the costs, gains and prerequisites of ASD?* This is further elaborated into three more detailed research questions: Research question1) What are the underlying principles and rules of ASD?, research question 2) What is the evidence regarding claimed effects and benefits of ASD? and research question 3) What are the prerequisites and context dependencies of ASD? To seek to answer these questions, four studies are planned: Study A) Literature study , study B) Systematic review, study C) Case-studies and Study D) Controlled experiment.

1. Introduction and motivation

Agile software development (ASD) is a relative new term within software engineering. Agile processes, or development methods, represent an apparently new approach for planning and managing software development projects. ASD differs from traditional approaches as it puts less emphasis on up-front plans and strict plan-based control and more on mechanisms for change management during the project. Despite being a new approach, the foundational principles of ASD are based on some existing principles and theories, both from the field of software engineering, information systems and others such as production management.

The origin of the term ASD lies in the agile manifesto[1] – a statement expressing a set of basic high-level principles and rules for software development: 1) individuals and interactions over processes and tools, 2) working software over comprehensive documentation, 3) customer collaboration over contract negotiation and 4) responding to change over following a plan. The manifesto was defined by a group of practitioners and theorists in 2001 and forms a credo which all so-called agile methods are based on. ASD has been met with both enthusiasm and skepticism by both industry and academia. In the extensive amount of literature on the subject, ASD is claimed to improve software quality, shorter time to market and reduced development costs. However – there is sparse evidence that this is correct and, in more detail, under which conditions these effects may occur. Some principles of ASD are investigated to some level, perhaps mainly pair programming[1], [2] and test-driven development[3]. Yet others need to be understood by practical experience. Given the potential that lies in ASD and the great interest in the industry on one side and the lack of well founded knowledge on costs, gains and premises on the other side, there is a clear need of extending the knowledge base on and practical use of ASD.

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[1] www.agilemanifesto.org

I have just recently started on my PhD-work and have not so far fully defined the research question(s). As my interest lies within ASD and related costs and gains I need input and advice on how to narrow the scope. One reasonable approach would be to define a research question addressing a detailed agile technique or practice such as test-driven development, active customer engagement, refactoring or others. Investigating a well defined and understood phenomenon makes it easier to define the independent and dependent variables to monitor in an experimental setting. However, I would like to consider the possibility to investigate some of the basic assumptions that ASD builds on to perhaps better understand the ASD as a whole and not just as a set of techniques and practices. Thus, potential topics could be the role and effect of stakeholder engagement (both internal and external), organizational and personnel prerequisites, needed support to maintain the flexible and responsive plan-do-check-act cycle and others. My problem here is to define how go from such a topic to the design of a controlled experiment.

2. Relevant prior work

The work will add to existing studies on ASD and related techniques and practices. The majority of existing studies seems to focus on sub-components such as isolated practices, techniques or tools - few studies looks into the use of whole or complete agile methods. In an ongoing systematic review of empirical studies on agile methods (experience with complete methods – not parts) we have out of several hundred initial identified published studies up to and including 2004 identified only 19 studies that hold sufficient quality. Out of these 15 are studies on the use of extreme programming. (The review is on-going and at the time we are including study reports from 2005. Results will be submitted for publication during 2006).

Of defined practices or techniques, pair-programming (e.g. [1] and [2]) and test-first/test-driven development (e.g. [4-8, 3], seems to be far more studied than others. The reason for this may be that these techniques are perceived as most innovative and promising and that they are practically easier to study in a controlled setting than other practices such as customer engagement, metaphor or others.

Another impression one may get from the state of the research is that few, if any, studies tries to look into the background and rationale of ASD. Why would such a strategy for software development be a better way than traditional approaches? What is the history behind the ideas? – clearly, some of the methodologists behind XP, Scrum and others are inspired and motivated by experience and research from other domains than software engineering, e.g. manufacturing and industrial design.

This very brief overview shows that even if there is a great industrial and academic interest in - and an extensive amount of research on topics related to ASD there is a need of more rigorous studies on a broader set of topics. The majority of studies are not suitable to guide the industry in the best possible adoption and use of agile methods.

In my PhD-work I would like to contribute to the knowledge base on ASD by studying and understanding the more fundamental concepts that lies behind. One part of this job would be to bring some more clarity to the various terms being used; iterative, incremental, evolutionary, participatory design, rapid application development, concurrent engineering, lean development and others. Further on, I see a need of starting to shape a description of the formal theory of the field. What are the most essential constructs and how do they relate? And further on – how do empiricism match the theory (confirm/correct/reject), both from the SE-domain but also from other domains? Concepts such as ‘self-organizing teams’, ‘change management', customer engagement', 'self-evaluation', 'creativity' and 'process control' may be promising candidates to start with.

3. Research Objectives, questions and hypotheses

Given the problem description, the main overall goal of the PHD-study is to answer the following question:

Main research question: ***What are the costs, gains and prerequisites of ASD?***

To reach a complementary answer, the study will in more detail look into the following underlying questions:

Research question i) What are the underlying principles and rules of ASD?
The agile manifesto and the handful of defined agile methods all share a common "philosophy" that involves concepts such as iterative development, frequent deliveries of working software, close stakeholder engagement, change response etc. Some of these concepts are apparently new; others are well defined and known. Together they form a distinct alternative to traditional plan-based approaches. While the various agile methods use terms and concepts slightly different and emphasize different parts the agile manifesto may bee seen as a common high-level definition of the concepts. However, there exist no good analysis and description of the history, fundamentals and rationale for these concepts.

Research question ii) What is the evidence regarding claimed effects and benefits of ASD? Examples are:

- Increased time to market
- Improved (product) quality
- Reduced cost

Most descriptions of agile method contain argumentation for the method, often by contrasting reference to obsolete traditional methods. Typically such descriptions refer to a great potential of improving the performance of the development process and the resulting product. Promised benefits relate to basic performance attributes such as time (to market/speed of development), cost and quality (in many forms). In addition several other underlying effects are promised. Examples are: improved developer satisfaction, increased simplicity, better test coverage (fewer errors), easy adoption and more. Most of these claimed effects are not backed up by sufficient empirical studies; however the knowledge base is growing. To move on, there is a need to produce and systematize more experience on the claimed effects of agile methods and related techniques and tools.

Research question iii) What are the prerequisites and context dependencies of ASD? Examples of varying context parameters are:

- Project size (small – medium – large)
- Form of delivery (tailor made, third-party components, standard product)
- Contract form (fixed price, running)
- Level of experience and experience (low - medium – high)
- Level of criticality (loss of comfort – loss of life)
- Tool support (no tool support – extensive tool support)

ASD, as any other type of method or strategy is presumably not suitable in every possible case – it is not the new silver bullet[9]. The most common perception is that ASD is best suited for small scale, small team and low-risk development projects [reference will be given later. Larman?]. However, there is little research that confirm this view.

4. Empirical study design and arrangements

The research in the PhD work will be based on four types of studies. Each study has a defined goal and result.

Study A) Literature study

- **Goal:** *To understand the foundational concepts of software engineering methodologies and agile methodologies in particular* (as far as it is described in the literature)
- **Result:** a magazine article, e.g. Software or Computer that summarizes lessons learned.
- Potential questions to be covered during the study:
  - What is the background and rationale of the basic concepts in ASD? For example the “rules” expressed in the Agile Manifesto.
  - What is relevant and useful experience and evidence from other (relevant) fields?
  - What is the common message in the “standard”-literature such as the books on the various agile methodologies – what do they share, how do they vary?
  - What are the most common claims or “propaganda” on agile methodologies? Examples are “better quality”, “lower cost” and “shorter time” (and others).
  - Enlighten the “missing” parts such as “mercantile issues”, “technical frameworks”, “stakeholder engagement” etc.
  - How can the most central terms be defined and related to each other?
  - What concepts from other domains, especially lean development can be related to ASD? Are the concepts congruent or do they vary?
- Useful and related literature: Turk et al. [10], Larman and Basili [11], Cochen et al. [12], Abrahamsson et al. [13] and the various books defining the handful of agile methodologies. (Many more references could (and will) be added here).

Study B) Systematic review

- **Goal:** *To systematize all qualified evidence on the use and effect of agile methodologies*. (This review includes only studies addressing “complete” method usage meaning that studies addressing single techniques are not included).
- **Result:** A journal article (a manuscript will be submitted by the end of 2006). A related article describing the survey strategy will also be published.

  Over the past ten years there are published numerous study reports addressing ASD. Both the focus and quality varies greatly and makes it hard to get an overall impression of the state of the research of the field. A few reviews are conducted to summarize existing work [12] and [13], although none of these are thorough systematic reviews. To contribute further on, I and some colleagues are conducting a systematic review according to the most recent guidelines [14] to systematize all relevant and qualified empirical studies on the use and effect of agile methodologies (up to and including 2005)

  Through the study we want to answer the following questions: 1) What is currently known about the benefits and limitations of agile software development? 2) What is the strength of the evidence in support of the claims regarding agile software development? And 3) What are the implications of these studies for the software industry and the research community?

To restrict the scope and sharpen the focus we have established a set of restrictions for selecting studies to be included in the review:

- Types of studies: Articles to be included in the review must present empirical data and pass the minimum quality threshold described below.
- Types of participants: Studies of both students and professional software developers will be included.
- Types of intervention: Inclusion of studies will not be restricted to any specific type of intervention.
- Types of outcome measures: Studies must include one of the primary outcomes of time-to-market, cost, or process or product quality to be included.

The following electronic databases are searched: ISI Web of Science, IEEE Xplore, ACM Digital Library, Kluwer Online, ScienceDirect – Elsevier, Springer, Wiley Inter Science Journal Finder, and Compendex. Further on, the following conference proceedings will be hand searched for research papers: XP, XP/Agile Universe, and Agile Development Conference.

The title, abstract, and keywords of the articles in the included electronic databases and conference proceedings was searched according to the following search parameters (list concatenated by inclusive OR): 1.agile AND software, 2.extreme programming, 3. xp AND software, 4. scrum AND software, 5.crystal AND software AND (clear OR orange OR red OR blue), 6. dsdm AND software, 7.fdd AND software, 8. feature AND driven AND development AND software, 9. lean AND software AND development

Studies were excluded if: 1) the study's focus, or main focus, was NOT agile software development and 2) the study did NOT present empirical data.

Each study was assessed independently with respect to their quality: *Rigour*: has a thorough and appropriate approach been applied to key research methods in the study? *Credibility*: are the findings well presented and meaningful? And, *Relevance*: how useful are the findings to the software industry and the research community?

The qualitative findings and conclusions of each study will be copied verbatim as reported by study authors into NVivo from QSR Software, a specialist software package for undertaking qualitative analysis of textual data. Examining these findings, every sentence or paragraph within the report of findings will be assigned a code to describe it. Two independent reviewers will look for similarities and differences between the codes in order to group them into a hierarchical tree structure of descriptive themes. A narrative summary of the findings across the studies will then be written and organized by the descriptive themes.

Study C) Case-studies

- **Goal:** *To collect and analyze data from industry to better understand the use and effect of agile methodologies and sub-practices in a realistic industrial context.*
- **Result:** A conference article per case-study.

Through the project funding my PhD-work I have contact with three SME's that all have software process improvement activities related to ASD. There is a potential of doing at least one case study at each of these companies.

Case 1: A software company with 80 employees and offices in the US, Europe and Asia. Main office and R&D-dept. in Oslo, Norway. They are providing a standard software product for marketing and customer surveys. I have a long relationship with this company as I have followed their SPI-initiatives for about five years and recently their adoption and use of the ASD-method *evolutionary project management* (Evo) [15] for more than two years. This study is reported in [16] and [17]. Recently, this company got engaged in plans to improve their test process (as part of Evo). They intend to adopt test-driven development (TDD) [3] at a large scale. The researcher-client relationship is arranged according to the principles of canonical action research [18]. The company's improvement goals are: *By the introduction of TDD, [Company name] expects to achieve the following improvements: 1) More errors discovered in development and accordingly less after release. 2) Reduced (proportionally) time used to maintain tests. And, 3) Improved product quality.* Potential research questions defined so far are: 1) Does TDD help to identify more errors during development than Test Last (TL)? 2) Are unit tests developed according to TDD less time consuming to maintain than tests developed according to TL 3) Does the use of TDD improve code quality compared to TL? 4) Does TDD inhibit the agile way of work for developers? Initially, the study is planned to be a case study, with a data collection plan inspired by GQM[19] however, detailed planning remains.

Case 2: A software consultancy company with 30+ employees. Main office in Oslo, Norway. Specializing in internet portals with an emphasis on graphical design. The cooperation in this case too will also be based on the principles of canonical action research. Initial discussions indicate improvement goals and research questions related to learning and reflection at individual and group-level. Further planning will take place during September/October 2006

Case 3: The software division in a company with about 50 employees that builds receiving stations for data from meteorological and Earth observation satellites. The company has recently adopted Scrum in one pilot project. Traditionally they have been following a strictly plan-based approach in their development processes but now see a need for more flexibility. The pilot project will be monitored and at least we will run a series of interviews to get an impression of the introduction of Scrum. Studies will be planned later to evaluate the effects of Scrum as compared to the traditional approach.

Study D) Controlled experiment

- **Goal:** *1) To understand the costs, gains and prerequisites of one or more agile sub-components, and 2) to gain practical experience in planning, executing and reporting a controlled experiment within the field of software engineering*.
- **Result:** a journal article (first or sole author) TSE, IST, JSS, etc.

(The description below is the first attempt to detail the various aspects of a plan for a controlled experiment – my intention is to give enough information to get valuable feedback - many details are still missing.)

At the time of writing, I have not yet decided in detail which focus to have in an experiment. However, based on the literature reviewed - and my understanding of software engineering and ASD so far I choose to investigate *active customer engagement* in agile software engineering processes. I find the active participation of the customers/users to be one of the most central and prominent aspects of ASD. It is included in various shapes and with varying emphasis in all defined ASD method as well as the method neutral agile manifesto. Further on I see active customer engagement to be an enabler or strongly attached practice to most of the other agile practices. Basically I would like to contrast active customer engagement with the role of the customer in plan based processes.

To define the experiment I will follow the experiment definition process described by Wohlin et al. [20]:

Object of study:	Strategy of engaging the customer(s) in the development process (traditional or agile)
Purpose:	To understand the effect active stakeholder engagement may have on process and product qualities
Quality focus:	Customer satisfaction, developer satisfaction
Perspective:	From the viewpoint of the customers (users) and developers
Context:	The experiment is run using second-year M.Sc.-students (in groups) as subjects implementing a software system.

Further on, I use the guidelines of the experimentation planning process:

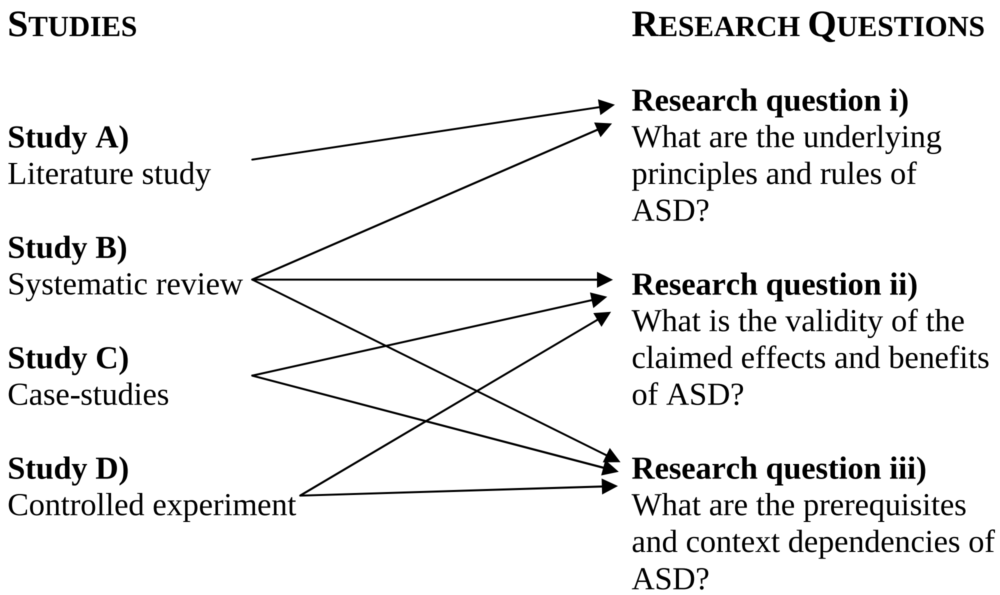
Context selection:	**-** Student experiment (200 students in groups/teams) - Toy problem (develop a system with no real customer)
Hypothesis statement:	H1: There is no difference in customer satisfaction regardless of customer engagement H2: There is no difference in developer satisfaction regardless of customer engagement
Independent variable:	Customer engagement strategy (two treatments; agile/traditional)
Dependent variables:	Customer satisfaction and developer satisfaction (These must be detailed and defined. Others may also be added later.)
Subjects:	Second year software engineering M.Sc.-students. Approximately 200 persons (that may be grouped in development teams of 4 – giving up to 50 teams). The students participate in a practical project-training program.
Sampling:	Complete population (no sub-group).

Exp. design: One factor with two treatments. (More factors may be added later – thus complicating the design…).

Analysis: t-tests for simple comparison of means. (Again, more factors/treatments will affect analysis…).

Each study is intended to contribute to answering one or more of the defined research questions, at least partially:

<u>Studies contributing to answering research questions</u>



5. Definition of metrics

As stated above, my PhD-work has just started and I have not yet got to the point where I have metrics specified in full detail. However, given the focus in my work the metrics to be used in the case studies and the experiment will be related to one or more of the following software engineering performance parameters:

- Quality (of the resulting product, may relate to any sub-definition of ISO 9126).
- Time-to-market (In many cases it seems that the speed of the development process is more important than the quality of the result).
- Cost (cost may be more than just money; risk can also be seen as a cost).

In more detail, the following metrics will be defined for the four studies:

- **Study A) Literature study:** No specific metrics will be investigated – although studies relating to time, cost or quality are highly relevant.
- **Study B) Systematic review:** Neither in this study, no specific metrics defined in advance will be investigated. However, the synthesis of the conclusions of the selected studies will group and collate data related to similar metrics. Typically, we are interested in empiricism on the effect of agile methods on time, cost and quality – and any other supporting metrics.

- **Study C) Case-studies:**
  Case 1: # errors introduced/development hour, unit-test maintainance time, code

quality (All of these metrics need further elaboration).
Case 2 and case 3: The case studies are being planned - no metrics defined so far.

- **Study D) Controlled experiment:** Customer satisfaction and developer satisfaction. (Must be refined). Other potential metrics (dependent variables) to be added to the design are: level of creativity and maintainability.

6. Data analysis methods

I will use various methods for data analysis for the different studies defined in chapter 4.

Study A) Literature study: The literature study will in practice be an "ad-hoc" process where I will pursue relevant references in literature I read. The planned article from the study will be written in a form close to an essay. The method may be defined as historical [21].

Study B) Systematic review: The (ongoing and incomplete) systematic review is done according to the principles defined by Kitchenham in [14]. Some guidelines are modified and extended to address qualitative studies.

Study C) Case-studies: The case-studies are all planned and will be conducted according to the principles of canonical action research as described by Davison et al. [18]. Some studies will be quantitatively oriented using a GQM-like approach as described by Basili [22], others will be qualitative studies using various methods for data analysis [23].

Study D) Controlled experiment: The controlled experiment will adopt common practices for experimentation in software engineering. Useful guidelines are Wohlin et al. [20], Zelkowitz and Wallace [21], Sjøberg et al. [24] (and many many others).

7. Validity threats and control

I am strongly motivated to do a PhD that has high industrial relevance. I mean that this type of research only holds value if the results are useful to practitioners – directly or indirectly with an emphasis on the first. I find it hard to ensure good validity and generalizability as my industrial studies will be single case-studies (small organizations) and a controlled experiment with the usual "problems" such as few subjects and an artificial/non-realistic setting. To improve, I will try to combine some of my cases to have multi-case studies (same research question – several cases). I am not sure how to ensure high internal and external validity in the experiment, however I find some of the recent literature discussing experimentation in software engineering useful and will adopt some guidelines here [24] and [25].

A brief view on validity threats[20] for the four studies:

Study A) Literature study: A literature study does not imply any particular threats to validity other than thoroughness and honesty in use and reference to previous work.

Study B) Systematic review: Much of the same considerations as for the literature study, however with even more need of thoroughness and completeness. Further on, many study reports within SE in general and within ASD in particular are qualitative studies. This implies a great challenge when it comes to systematizing results.

Study C) Case-studies: In general, when it comes to case studies it is important to control, or at least understand the effect of, confounding factors. In small case studies the problem studied may not be the same in larger settings. The perhaps most serious threat to the validity of a case study is the lack of control and thus problems in seeing the causes behind the effects being studied.

Study D) Controlled experiment: Four types of validity threats are briefly commented: 1) To ensure internal validity I must control all other factors believed to affect the dependent variables (customer and developer satisfaction). This may be ensured by having homogeneous experiment and control groups. 2) External validity may be a problem in this study as the subjects are students and the population I want to generalize the results to are professionals. 3) The construct validity is potentially threatened if the independent variable (customer engagement strategy) is poorly reflected in the treatment and accordingly the dependent variables are poorly reflected in the outcome of the treatment. 4) To ensure conclusion validity I plan to run a pilot study to ensure that there is a statistical relationship between the treatment and the outcome.

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