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Evaluation of a Descriptive Approach for Product Portfolio Modeling – A No-Success Story and What we can Learn From it

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Abstract

Increasing product variety and shorter life cycles require new descriptive approaches to advance multiple products in product portfolios. This article focuses on the support, application, and success evaluation of an initial descriptive model for the advancement of product portfolios. For this purpose, requirements for the evaluation are determined. A workshop concept was developed and evaluated with 161 participants divided into test and control groups. While the evaluation shows no significant improvement between the groups, the analysis shows differences in performance and indications concerning the workshop concept, revealing learnings and limitations for conducting future studies.

Keywords: System Generation Engineering; Product Portfolio; Product Management; Descriptive Model; Live-Lab; Evaluation;

1. Introduction

The advancement of product portfolios is a key factor for the long-term success of companies [1]. Shorter life cycles, increasing individualization, and the growing complexity of products are challenging product developers and require new methods to support the advancement of the product portfolio [2,3].

In an interview study with seven companies, the advancement of product portfolios in companies was examined, and the need for a process and a descriptive model was specified [4]. Based on the interview study and a literature investigation, an ontology was developed for the research area of future-robust advancement of product portfolios to facilitate communication between universities and companies [5]. Based on the interview study and already existing approaches to model product portfolios, an initial descriptive approach was developed to support the advancement of product portfolios [6]. For example, an initial version of a descriptive model for the advancement of product portfolios based on the model of SGE – System Generation Engineering was developed [7,6]. The approach takes up the elements and the structure of the product portfolio. Within the approach, the advancement of the product portfolio is modeled, with the help of references from the company's own and other products or existing systems [6]. The initial model was expanded in the next iteration in order to be able to describe the elements of the product portfolio precisely and comprehensively in an early phase of the product development process [8]. Due to the solution-open character of the product profiles, the model represents the connection to strategic product planning. The approaches developed were initially validated as part of the creation process. However, a comprehensive evaluation has not yet been carried out.

In this paper, the initial descriptive model will be evaluated in a live lab with 160 participants. An evaluation concept is created and finally carried out in the live lab in a test and control group setting according to the Design Research Methodology. [9].

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2. Theoretical background

The background of the research object (the initial descriptive approach) and the research environment (the live lab – mechanical design IV (MDIV) in which the object is evaluated are explained in the following chapter.

2.1. Fundamentals of the research object - descriptive model

The object of research, the descriptive approach for the advancement of product portfolios, combines the sub-areas of portfolio management, strategic product planning, and development based on references according to the model of SGE-System Generation Engineering as shown in figure 1 [10].

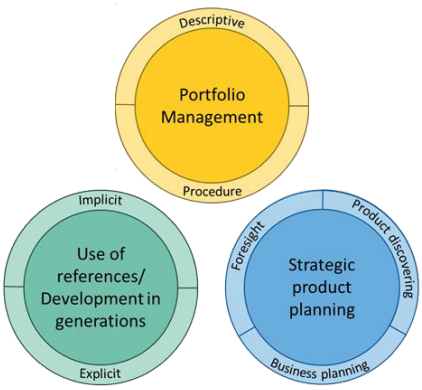

Fig. 1. The research object combines the three fields of research.

As the first descriptive element, an ontology was developed as a fundamental linguistic basis founded on the research areas and considering the practical terms used in companies due to an interview study [5].

The initial descriptive model for the advancement of product portfolios, shown in figure 2, takes up the structuring of product portfolios in 4 levels [11,4] and defines these elements across the different product generations [6].

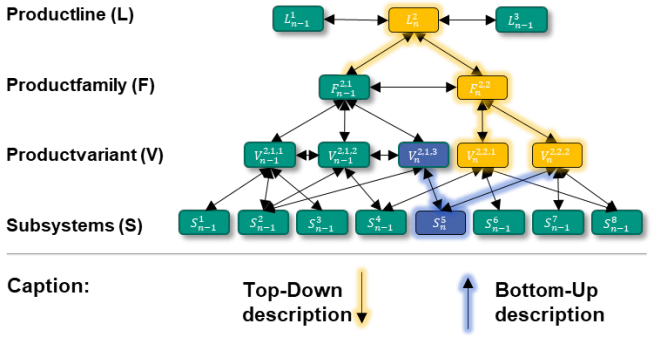

Fig. 2. Product portfolio structuring based on four levels. Indices for the respective product generation $G_{i=n}$ or previous generation $G_{i=n-1}$[6].

The descriptive approach provides a solution-open description of the elements via level-specific product profiles [12,8]. Product lines as the top level are often oriented toward the application areas of the respective companies. The product lines are further subdivided into product families, which combine similar variants of products. The product family profile enables the product variants of a family to be mapped by modeling according to the laws of variant generation.

The systems that are perceived as products by the customer are located at the variant level. The products differ in their variants according to their value or functional scope. However, the basic structure and core benefits of all variants remain the same. The subsystem level picks up the assemblies required to realize the product. The subsystem level can be regarded as fractally expandable. In modular systems, for example, subsystems are often taken up again in several products [11].

2.2. Fundamentals of the research environment Mechanical Design IV (MDIV)

The research object will be evaluated in the research environment “Mechanical Design IV (MDIV)” at the Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany. As part of the MDIV live lab, each year 150-200 students will develop a technical system in teams of 3 to 5 people supervised by one tutor and guided by a total of 4 supervisors. The live lab as a workshop to a correlating tutorial and lecture deals with a real complex task with project milestones. The conditions of the live lab are more controllable than an industrial evaluation [13].

The project work is divided into three phases throughout the semester. At the end of each phase, the students present their current work progress to tutors in a workshop. The project work attempts to reflect the demands of a real development and also takes up the advancement of several variants of a tractor powertrain. The focus here is on the further development of two variants of the powertrain. The cohort examined in this study faced the challenge of developing a modular drivetrain for a pure combustion engine drive and a parallel hybridized drive. To prepare the students for development practice, which does not start from a blank sheet of paper, but always has references as described in the model of SGE - System Generation Engineering according to Albers [7], the product documentation, such as flowcharts or technical drawings of a selected team from the previous year, is made available as a reference [13]. Thus, the power-split hybrid drivetrain of the previous generation was used as a reference. Figure 3 shows which subsystems of the reference product need to be fundamentally revised due to the new requirements and which ones can be carried over.

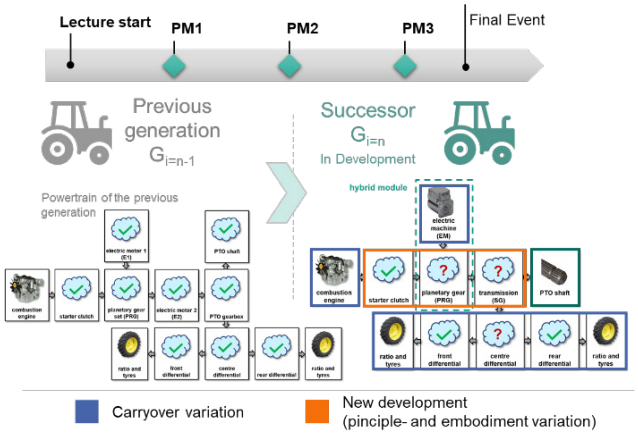

Fig. 3. The workshop comprises three project milestones (PM) for the advancement of an existing generation of a tractor with a power-split hybrid into a new generation with a modular hybrid drive.

3. Research Design

Due to individualization and the growing complexity of systems, the variety of products in the product portfolio is increasing. This increase presents companies with a challenge and means that existing approaches and methods are often no longer sufficient [3]. As part of an interview study with seven companies, the need for action was identified, revealing the need for a process- and a descriptive model. [4]

This paper aims to evaluate a first initial descriptive model (research object) in the live lab "Mechanical Design IV" (research environment). An attempt is made to investigate whether the approach of the initial description model is understandable and can be used to structure product portfolios.

In order to achieve the aim of the paper, the following research questions are posed, which are to be answered in the paper:

RQ1: What requirements do the research approach and the research environment impose on the creation of an evaluation concept? (Descriptive study I)

RQ2: How can a workshop to evaluate an initial descriptive model be designed? (Prescriptive study)

RQ3: To what extent is the derived workshop concept capable to evaluate the descriptive model and what conclusions can be drawn? (Descriptive study II)

In order to achieve the aim of the present study, the work is based on the Design Research Methodology (DRM) approach in accordance with Blessing and Chakrabarti as shown in figure 4 [9].

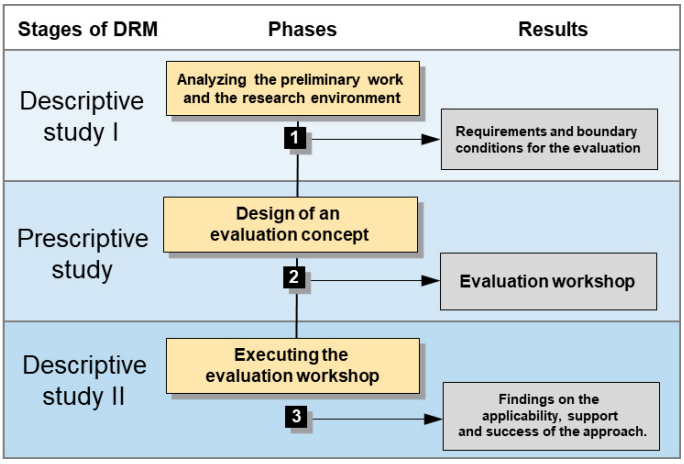

Fig. 4. The phases and corresponding Results are based on the stages of DRM

The descriptive study I is divided into two perspectives. Firstly, the boundary conditions of the live lab as a research environment for the design and implementation of the workshop are derived. Subsequently, the requirements for the evaluation of the initial descriptive model are also determined in the sense of the research object. In conclusion, the descriptive study I aims to answer research question 1 and provides the knowledge base for the development of a workshop concept.

Based on the results of the requirements for the evaluation of the initial description model and the associated limitations of the live lab as a research environment, a workshop concept for the application of the description model will be developed in the prescriptive study to answer research question 2.

The workshop concept is then carried out in the Mechanical Design IV course with 135 participants in the second descriptive study to answer research question 3. The evaluation of the approach was conducted via an observational study by the supervisors and tutors as well as through an anonymous survey of the participants in the live lab.

4. Results

In accordance with the research design and the research questions posed, the results are divided into the following three chapters: 4.1 Descriptive study I - Requirements for the evaluation of the initial descriptive model and constraints of the live lab setting, 4.2 Prescriptive study - development of an evaluation and workshop concept, and 4.3 Descriptive study II - Execution and evaluation of the workshop.

4.1. DS I - Requirements for the evaluation of the initial descriptive model and constraints of the live lab setting

The main objective of the evaluation concept is to evaluate the descriptive model. To achieve this goal, however, the applicability in the research environment must also be taken into account. Therefore, the requirements for the development of the evaluation concept are divided into two areas. Firstly, the requirements (R) for the descriptive model to be evaluated (chapter 4.1.1) and the boundary conditions (BC) coming from the associated research environment (chapter 4.1.2).

4.1.1. Requirements of the descriptive model (research object)

The requirements for the evaluation of the description model are also based on the DRM Design Research Methodology [9]. Statements about the applicability (R1), to what extent the procedure is feasible, about the support potential (R2), to what extent the procedure supports the accomplishment of the task and an improvement of the results in terms of success evaluation (R3) are to be examined. The aim is to carry out an initial validation of the extent to which developers understand and can implement the approach. However, the requirements for the evaluation of the descriptive model are limited by the research environment.

4.1.2. Boundary conditions based on the research environment.

The research environment represents the live lab Mechanical Design IV as presented in the theoretical background (chapter 2). The second of three milestones is aimed for, as the teams have already completed one milestone and have been able to form but still have sufficient time before the exam. In project milestone two, a time of 30 minutes is possible for the research task (BC1). Due to these constraints, the evaluation workshop must be highly simplified and mapped to a short period of time.

Another constraint is the experience of the study participants. The study participants are in their undergraduate studies and, on average, have no previous experience in the field of product portfolio management (BC2), which stands in contrast to the application in the later field of application in

industry. The group size has to be set to 4-5 persons due to the research environment (BC3).

In summary, descriptive study I answers the first research question by deriving the requirements and boundary conditions for the design of an evaluation concept.

4.2. PS - Development of an evaluation and workshop concept

The design of the workshop must be integrated into the course schedule. In order to determine differences through the use of the descriptive model, a test and control group design was chosen for the workshop.

As shown in figure 5, The evaluation concept is structured in a way that the control group without methodology is carried out at the beginning in the first two blocks of appointments. The test groups are then held in the C and D blocks. This structure prevents elements of the descriptive model from being communicated from the test to the control groups.

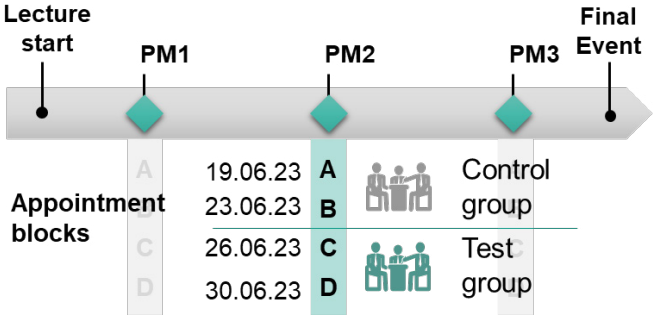

Fig. 5. The study was conducted at the second milestone of the event in a test and control group design. Participants will remain assigned to blocks A-D across all three project milestones (PM).

Information folders are prepared for the content of the workshop task. The information folder for the test group comprises a total of 16 pages and includes an introduction (4.2.1), task description and basic information (4.2.2), and a section on methodology explaining the descriptive model (4.2.3). In the last chapter, the research object is evaluated (4.2.4). The control group receives the identical information folder (7 pages) except for the methodology section.

4.2.1. Introduction

The introduction briefly outlines the fact that the kind of development that often occurs in teaching - from a single or no reference product to a single successor product - does not correspond to the practice of many companies [4]. Furthermore, the term innovation is introduced to avoid misinterpretations in the evaluation. [12].

4.2.2. Task description and basic information

The information folder contains the work assignment as well as the information that are necessary to complete the task as well as the specific task itself. The existing products (tractors, combine harvesters, lawnmowers, etc.) are to be further developed, taking into account changes in the environment. Key guiding questions were asked: Q1 - How is the product portfolio structured? Q2 - Which products can be removed from the product profile in the future and which should be added? Q3 - What are the similarities, differences and interactions between the individual products?

The information folder also includes information on current developments within the company, such as the hybrid module for tractors or a 9-speed manual transmission. The company's own developments serve as a reference for the derivation of new product ideas.

Last, the information folder also contains information on various environmental changes that can have an impact on areas of the product portfolio (figure 6)— represented as, e.g., newspaper articles, trends, or scenarios.

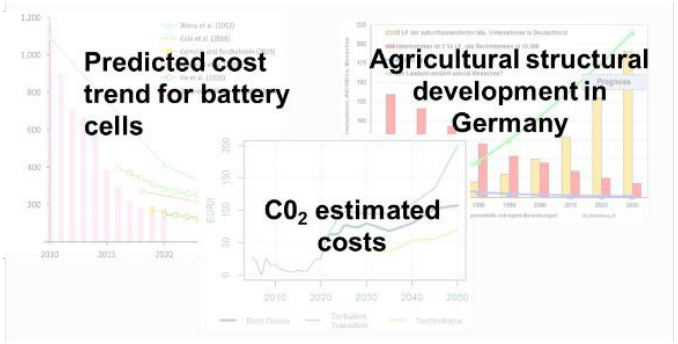

Fig. 6. Various trends that were made available to the developers as part of the information folder.

4.2.3. Methodology

The test and control groups differ in terms of the methodology in the info folder. The methodology includes a structuring proposal and templates for structuring, as shown in figure 7. The methodology is intended to make it possible to model product portfolios more efficiently by not having to consider all products individually. With the descriptive approach it is possible to model several products simultaneously via a description at the product family and product line level, which take up the elements of the product portfolio underneath [8].

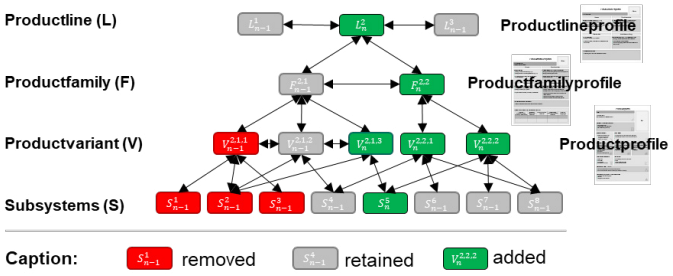

Fig. 7. A schematic representation of the descriptive model [8].

4.2.4. Evaluation

After completing the development task, an online survey is conducted with the participants. A distinction in the survey is made between the tutors observing and the developers. The structure of the surveys is oriented towards the DRM and addresses the application evaluation, support evaluation and success evaluation. The survey is anonymous and is decoupled from the evaluation of the project session. The research question two is answered by the derived workshop concept in a test and control group design with a subsequent survey.

4.3. DS II - Execution and evaluation of the workshop.

The following chapter describes the implementation and evaluation of the previously derived evaluation concept. The implementation was carried out from 03.2023 to 06.2023 with a total of 160 students and 26 tutors, which were divided as shown in figure 8. The bold number in front of the brackets indicates the number of participants in the survey, the number in brackets shows the total number of participants in the workshop.

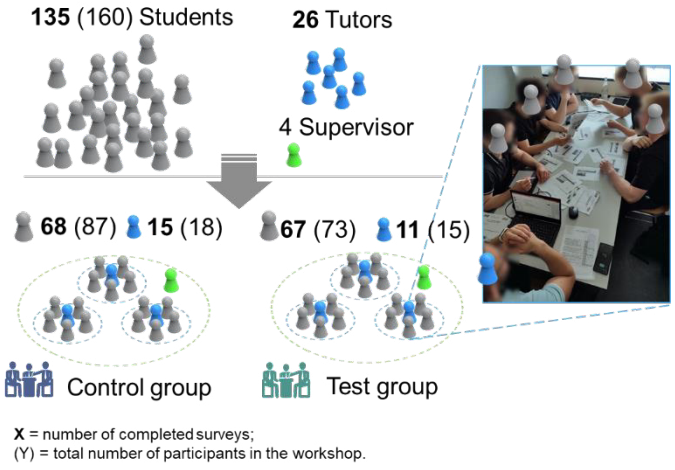

Fig. 8. The cohort of 160 students was divided into test and control groups with a deviation of 14 people.

The results include the observations and statements of the workshop groups (students and tutors) as well as the results of the online survey shown in figure 9, to answer research question three. Exemplary statements are:

S1 - "The methodology could be applied in principle, but there was too little time to carry it out comprehensively and in detail. The potential was therefore not fully realized."

S2 - "In my opinion, the method is not applicable in the short time available (especially because the task is quite long and therefore time-consuming to read). If you had 10 minutes more you could certainly work with it."

According to the students' self-assessment, the results of the evaluation in figure 9 shows no improvement through the use of the methodology. The students with methodology tend to be overburdened compared to the students without methodology. Furthermore, the processing time for the methodology group is evaluated as too short.

The overall grading and the grading of the workshop two, which are not influenced by the research task, shows a difference between the test and control group.

5. Discussion

In preparation for the workshop, the research environment's boundary conditions and the research subject's requirements were considered and incorporated into the development of an evaluation approach. Nevertheless, problem areas (P) and correlating learnings (L) arose during the implementation of the research project.

The descriptive study II shows a compromise in the research design. On the one hand, the approach represents a complex research subject that has been dealt with in companies for years [4]. However, the scope of the course only allows a brief excerpt to be considered. The task has been greatly simplified compared to practice. A live lab, in contrast, makes it possible to control the boundary conditions and settings better than in a corporate context [14]. A test and control group design in which 160 developers perform the same task in the same conditions would not have been possible in the industry.

The results show that, according to the participants, the methodology within the workshop concept does not lead to any improvement in support, application and success evaluation. According to the developers' own statements and the tutors'

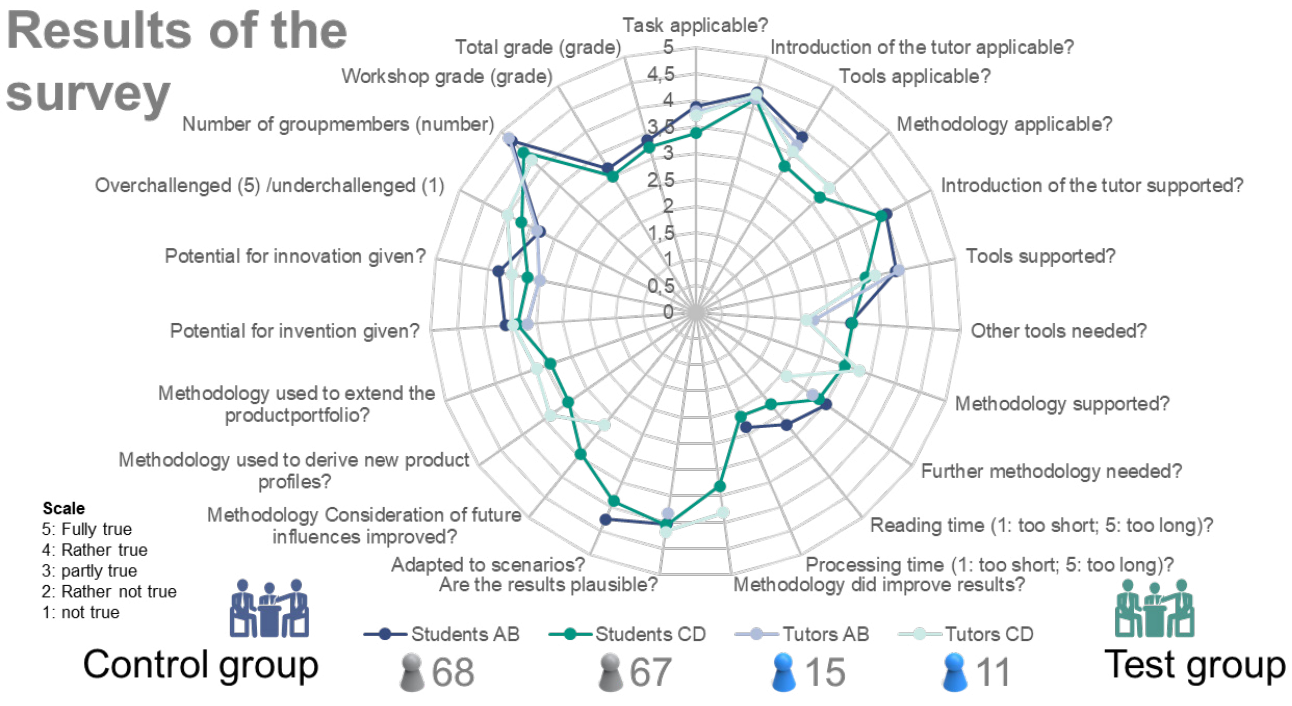

Fig. 9. The results of the anonymous online survey show no improvement with methodological support. The overload and the assessment of reading time provided worsened with methodological support.

observations, the approach was understood and partially applicable. The reasons for this can be found directly in the evaluation results and correlating statements.

The statements of the developers indicate that the selected workshop concept has too short a working time (P1). (Statements S1-S4). In particular, the test group rated the overload and reading time less suitable than the control group. This is due to the fact that the scope of the information folder to be read is even greater in the test group due to the additional methodology chapter. In order to ensure comparability, the processing time must be extended according to the additional time required to read the methodology (L1). The live lab character not only affects the boundary condition of limited time but also the experience of the developers. There was no prior knowledge of the company's product portfolio nor of the basics of portfolio management, unlike in the industrial application. The level of support required for an approach differs between participants in the live lab, students in their fourth semester, and product managers with a degree and initial professional experience (P2). Therefore, the difference in experience between study participants and later implementers has to be as low as possible, to obtain valid studies. (L2).

Differences can also be identified due to the setup of the groups. For example, the group size in the test group is smaller than that in the control group (P3) (average students per group: control group 4,75 / test group 4,43). There were also differences in performance in the workshop between the test and control group. The participants in the control group achieved an average of 3,17 points out of 4, while the test group only achieved 3,01 points (P4). All awards for outstanding performance (presentation, calculation, creativity and design) in the workshop were also achieved by the control group. Here, it should be noted that the research task itself is not included in the assessment of the workshop. This indicates that there are differences in performance between early and later workshop groups. Therefore, a more even distribution of test and control groups across the project sessions of a live lab has to be undertaken (L4).

6. Conclusion and Limitations

The research conducted in this paper does not show a success of the methodological support in a live lab setting. Various problem areas can be identified: Workshop concept (P1), experience of study participants (P2), different group sizes (P4), and performance differences in test and control group (P3). A very complex topic, which in the actual use case is addressed to experts with professional experience, was applied in a very short time with developers with little or no previous experience in product management.

Summing up, the study provides learnings for future studies in live labs. For example, it is important to ensure that the methodological support does not massively shorten the processing time (L1). Furthermore, the level of knowledge between study participants and later implementers must not diverge too greatly (L2). There are also differences in performance over the semester, which must be taken into account (L3). However, the study shows the potential applicability of the approach, provided that the research setting is adapted (S1 and S3). For the reasons explained, the present study is not considered representative for the evaluation of a company-oriented support approach.

7. Outlook

In future studies in live labs, the research object should be much closer to the corresponding level of knowledge of the study participants. Alternatively, research approaches that require less time in execution, e.g. approaches to support creativity would also be suitable. In the next step, a more comprehensive study with experienced industry participants over a longer time horizon is planned to evaluate the methodology and descriptive model.

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