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A METHODOLOGY TO IDENTIFY AND ADDRESS IMPROVEMENT POTENTIALS IN COMMUNICATION PROCESSES OF DISTRIBUTED PRODUCT DEVELOPMENT – AN INITIAL APPROACH

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Abstract

The advantages of distributed development teams help companies to address megatrends like globalization and individualization. However, development teams are facing challenges according to increasing requirements on communication processes. This approach provides a methodology to identify and address improvement potentials in communication processes of distributed product development by including the dimensions technology, organization and human involved in the development process. The validation of the methodology's process steps was carried out together with a machine tool manufacturer.

Keywords: distributed design, communication, modularisation, human-centred design, agile systems design (ASD)

1. Introduction

Megatrends such as globalization, individualization and digitalization lead to shorter product life cycles and changed customer and employee. A promising part to manage the megatrends is the expansion of product development into distributed or virtual teams. Today, almost 50 % of more than 2000 surveyed decision-makers, stated distributed teams as a short- and a medium-term key challenge in global product development (Ebert, 2019). The trend of recent years suggests that soon many globally developing companies will be confronted with distributed product development where teams have to work together distributed on the same tasks, as the increasing complexity of products requires intensified collaboration. Faced with these changes, today's organizations are focusing the creation of digital workspaces for a limitless development environment without resource constraints. As companies have little experience in this area, employees feel left alone in the application of the changed working environment resulting in increasing uncertainty and dissatisfaction in the development process. Aspects such as data exchange, as well as communication processes via different tools, which often do not yet function trouble-free, intensify these uncertainties. Eventually, this leads to an increased inefficiency in communication processes and to deviations from the desired target state as well as to negative effects on employee satisfaction. Agile approaches, now also emerging in hardware industries, offer opportunities to counter these uncertainties and to address the increased requirements on communication. There is currently a lack of understanding of the individual improvement potentials owed by poorly functioning communication processes in distributed product development. In order to identify, quantify and address these potentials, the challenge is to support the distributed development teams with a methodology to

enable the teams to ultimately find, argue and implement measures for improving communication in distributed product development situations specified for individual development environments.

2. State of research

2.1. Distributed product development

As a result of the implementation of new processes, methods and tools, which in the course of digitalization, globalization and individualization are being introduced into product development in order to manage complex interrelationships, product development in distributed teams is emerging as a key challenge (Ebert, 2019). In addition to the term distributed teams, the term virtual teams is often used. Lipnack and Stamps (1997) define a virtual team as a group of people who work independently of each other across space, time and organizational conditions to achieve a common goal. In this work, the term distributed product development refers to the joint product development between at least two geographically separated team members according to the definition of Kern (2005). In conclusion, it can be stated that the operation system of the product development process as a socio-technical system is distributed across different locations. According to Albers et al. (2016b) the operation system includes activities, methods and tools as well as the resources needed for their execution.

According to Stöger and Thomas (2007) one of the most visible changes and thus also one of the greatest challenges is distributed communication using technical aids. Telephone and video conferencing can, for example, serve as a substitute for personal meetings and thus save travel time and money (Stöger and Thomas, 2007). Nevertheless, media-based communication is often associated with a significantly increased initiation effort and, compared to personal conversations, media can almost never ensure truly complete communication pursuant to Kuster et al. (2011). Depending on the medium, body language, eye contact, posture and extra-communicative actions are often partially or completely lost (Kuster et al., 2011). According to Konradt and Hertel (2002) electronic media are mainly used for communication, but are seen as a central challenge in distributed product development. In order to deal with the changing technical and organizational requirements, developers need additional competencies according to Bavendiek et al. (2018).

Duehr et al. (2019) compiles a collection of success factors for distributed product development based on the literature. According to Boutellier et al. (2008), on the one hand, an incremental innovation, autonomous project tasks, existing knowledge in explicit form and redundantly available resources are required for a distributed execution of projects. Weinkauf and Woywode (2004) on the other hand, focus more on team-specific success factors, such as common working languages, heterogeneous team members, existing support from top management, functioning communication channels and a common understanding of objectives. This is supplemented by the success factors from Horwitz et al. (2006) focusing on communication, defined roles, trust and commitment. Ahuja (2017) has an increased perspective with success factors like organizational culture, effective HR practices, leadership and faith, whereas Meyer-Eschenbach and Blessing (2005) focuses more on the specific harmonized development process, detailed project organization and same IT infrastructure. By taking a holistic view of the literature, communication can be identified as a central success factor in distributed product development. This is confirmed by Ostergaard and Summers (2009): "Communication can be regarded as a central factor in many group situations, but it is particularly important when a development team is distributed".

To support distributed communication processes, agile practices and values are important. However, Hossain et al. (2009) revealed that agile practices like Scrum need to be extended or modified when implementing it to support communication in distributed development teams. Albers et al. (2019b) provide with the approach ASD - Agile Systems Design an opportunity for agile adaptation of flexible and structuring elements in the product development process. According to ASD - Agile Systems Design, development teams can select a suitable procedure for the considered process level depending on the development situation and level of uncertainty. For the application of ASD - Agile Systems Design in the development of mechatronic systems the methodology supports development teams with nine basic principles. This creates a solution space for company- and situation-specific practices (e.g. development methods, team structures, maturity levels, etc.), so developers can implement a certain agility in the process depending on the situation and align their actions accordingly. (Albers et al., 2019b)

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2.2. Three design dimensions: Technology, organization and people

The above described challenges for distributed product development must now be addressed holistically. The TOP model (technology, organization, people), also known as HOT model (human, organization, technology) applied by Bullinger et al. (1997) in the context of knowledge management ensures the sustainable establishment of improvements in the company by holistically incorporating the three design dimensions of people, technology and organization. As in the transformation process to distributed product development similar objectives are to be pursued, the model can help to have a holistic consideration of all necessary aspects.

Technology: Distributed collaboration can only be achieved through the existence of appropriate technical systems. For this purpose, a company examines which additional new information and communication technologies are needed to best enable and support employees for the new type of collaboration (Gerhards and Trauner, 2011). With the introduction of new technology three main reasons for upcoming problems are often immature technology, unsuitable technology and complex technology (Ulich, 1997).

Organization: In the TOP approach, organization is understood as a living social system in which the actions of individuals are related to each other through communication. The term organization is used when the decisions of individuals become binding for the actions of many (Michulitz et al., 2008; Bischoff et al., 2011). Since the organization suddenly grows strongly through the incorporation of an additional location, new processes, procedures and communication channels must be created. From the point of view of a development team, the aim is to adapt the organization and distribution of tasks in daily distributed teamwork. Establishing these organizational changes in turn requires the necessary technical prerequisites, as well as the will of the employees to learn how to deal with them and to promote new approaches.

People: According to Albers et al. (2019a) the human being is the central element in product development. Therefore, new technologies should never be seen as limitations, but always as empowerment, where technology is always a tool and never a purpose of design (Hartmann, 2005; Bischoff et al., 2011). Especially when introducing new technologies as well as new processes and methods, care must be taken to develop people accordingly in order to adapt the corporate culture to the new framework conditions.

2.3. Problem solving to identify and address improvement potentials

Albers et al. (2005) describes a problem as a deviation between the undesirable initial (actual state) and the desired final state (target state) combined with the partially unknown path from the actual state to the target state. Applied to systems engineering, a problem is a deviation between the arbitrarily little known target system and a selected arbitrarily vague object system, which interact via the partially unknown action system. The SPALTEN methodology describes a universal approach to problem solving for problems of varying complexity. The methodology provides a framework that guides the developer through the problem-solving process in a structured way and splits the problem to be solved into smaller, manageable problems. The word SPALTEN is an acronym that stands for the activities of problem solving (Albers et al., 2016a): Situation Analysis (**S**ituationsanalyse); Problem Containment (**P**robleme ingrenzung); Search for Alternative Solutions (**A**lternative Lösungssuche); Selection of Solutions (**L**ösungsauswahl); Analysis of the Level of Fulfilment (**T**ragweitenanalyse); Make Decision/Implement (**E**ntscheiden/Umsetzten); Recapitulate/Learn (**N**achbereiten/Lernen).

SPALTEN is a so-called breathing process. In two successive activities it is continuously generated and condensed. Due to the sub-divisibility of each individual activity into a new SPALTEN process, which in turn can be solved systematically, this methodology has a fractal character. It can be applied to future-oriented as well as spontaneously occurring problems. By the constant focus on the problem and the dependencies to boundary conditions, an optimal cost-benefit ratio is achieved. (Albers et al., 2005)

In conclusion, the SPALTEN methodology represents a universal aid for coping with problems of different levels of complexity and under different boundary conditions. Therefore, this problem solving method is suitable to serve as a reference process for the goal pursued in this project.

3. Aim of research and methodology

Distributed product development is a good way to support the emerging changes coming up with the current megatrends, but it also comes with challenges itself. The theoretical possibility of distributed team

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collaboration, based on technical tools available on the market, often leads to the misconception that distributed collaboration can be implemented without problems and procured tools will be used by the employees. In particular, the topic of communication in distributed collaboration requires increased attention. The three dimensions of the TOP model (technology, organization and people) must be addressed in order to support the change process holistically. For this purpose, success-relevant influencing factors from literature describe the essential aspects to which special attention must be paid to aim for a successful distributed development process. Companies must create the technical prerequisites and adapt methods and processes as well as changes in the mind-sets of employees are necessary. As long as an organization is still in the unstructured adaption process to the new conditions coming with distributed collaboration, losses arise, especially in the increasingly necessary communication in distributed product development processes. This process must be methodically supported and the losses be identified and presented transparently in order to create awareness of challenges in this area within the company and ultimately to define measures for addressing the potential arising from the losses.

So far, however, there has been no approach that addresses the structured analysis of improvement potentials based on the individually prevailing distributed development situations of an organization. Therefore, the overall long-term research goal is the development of a methodically approach for the holistic identification and addressing of potentials in communication processes of distributed product development.

In development organizations in which success factors have not yet been addressed and in which the dimensions technology, organization and people have not been integrated by implementing new measures, the difference between the actual and target state results in deficiencies. Within the framework of this publication, a first contribution will be made to identify the necessary process steps of such an approach and to validate the process steps through a preliminary study. Therefore, the following research questions arise:

- *Which success factors need to be addressed to enable the identification and addressing of improvement potentials in distributed product development?*
- *Which process steps must a methodical support contain in order to systematically support the identification and addressing of improvement potentials in communication processes of distributed product development?*

This work was carried out according to the Design Research Methodology (DRM) (Blessing and Chakrabarti, 2009). After a literature review, Descriptive Study 1 validates the success factors of distributed product development through expert interviews in the research environment to answer the first research question. In the Prescriptive Study, the necessary process steps of the approach based on the SPALTEN process are synthesized. The process steps are finally validated in the Descriptive Study 2 through implementation in the research environment based on several quantitative surveys and qualitative feedback.

A known machine tool manufacturer serves as the research environment for the early validation of the approach. The company responds to the changes in a highly individualized and increasingly complex world of product development by introducing a modular system to reduce the internal variety of variants and at the same time offer customers a high external variety of their products. Formerly developed independently at different locations, products that now contain the same modules in a modular system force development teams from different locations to develop the modules together. For this purpose, development teams are ultimately formed at different locations and are using agile practices like Scrum to handle the increased requirements on communication. In this case, the distributed development team which served as application environment for the methodology consists of team members at locations in Switzerland, Eastern and Southern Germany leading in an unavoidable daily communication.

4. A methodology to identify and address improvement potentials in communication processes of distributed product development

In order to achieve the overarching goal to provide methodical support for the identification and addressing of improvement potentials in communication processes of distributed product development,

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the following objectives that build the basis on which the process steps of the methodology are determined:

- Consideration of the prevailing development situation
- Identification of individual improvement potentials in communication processes in distributed product development
- Definition of measures to address the identified improvement potentials

The analysis of the different SPALTEN process steps and the transfer of the given objectives of the methodology resulted in the reference process shown in Figure 1.

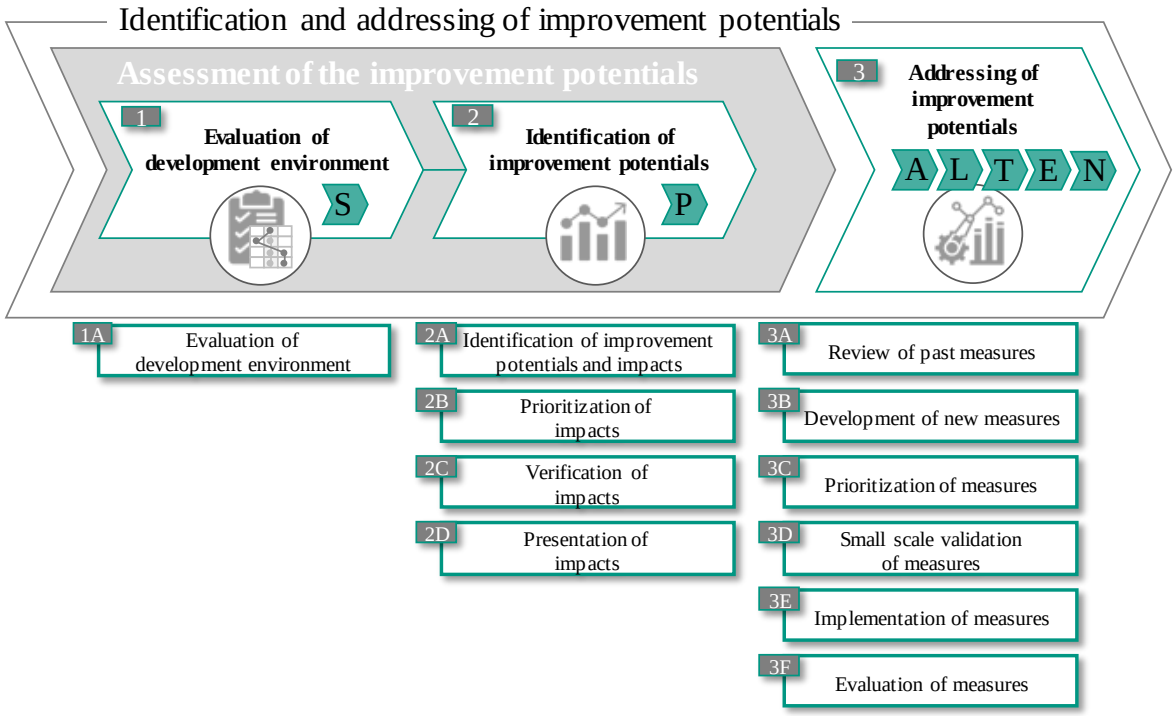

Figure 1. Process steps of the methodology

The structure of the reference process of the methodology is divided into three main phases: Evaluation of development environment, identification of improvement potentials and addressing of improvement potentials. Behind each phase there are one or more process steps that need to be carried out to achieve the goal of the respective phase. First, it is necessary to get an overview over the development situation where improvement potentials need to be identified. This entails the characterization of the prevailing development situation of the environment in which the methodology is to be applied. Therefore, a workshop with the development team and other stakeholders can be conducted (1A). Following in phase 2, the improvement potentials and their impacts can be identified within method 2A by a workshop in which the relevant team members participate or by a qualitative interview that either can address the distributed development team or the management. After that, the prioritization (2B), the verification (2C) and the presentation (2D) of impacts of the identified potentials need to take place to define the focus of the following phase. In the third phase, the identification of measures to address the most significant potentials is conducted. For that, measures that were already taken into account in previous improvement activities but did not lead to the desired improvement can be considered (3A). In addition, new measures can be developed in a workshop with the team members (3B). When developing measures holistically, the three design dimensions of the TOP model technology, organization and people (see section 2.2) must always be considered by the workshop participants. Following, the prioritization with method 3C and a first validation of the measures (3D) with the best effort to use ratio in a small scale takes place. Finally, after the successful and positive validation in small scale, the measures will be implemented on a large scale (3E) and eventually be validated to recapitulate and learn (3F).

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The combination of some or all of these and as well further additional process steps forms a modular approach and a methodology to identify and address potentials in communication processes of distributed product development. It must be said, however, that behind each process step there are several methods by which the goal of the respective process step can be achieved. The compilation of these methods was not considered in this publication. Thus, it can be stated that the approach is not dogmatic but needs to be applied pragmatically in dependence of the prevailing conditions of the addressed development situation by choosing a suitable method.

5. Preliminary validation of the methodology's process steps

In order to early validate the process steps of the introduced methodology with the goal to identify and address improvement potentials in communication processes of distributed product development in section 4, a first preliminary study was carried out in the industrial product development environment. Based on the developed reference process shown in Figure 1, methods were selected that could be applied in the environment to perform the specified process step. Due to the extensive study, only the implementation and results of the application of selected process steps and the respective used methods from each main phase are presented in the next sections.

5.1. Evaluation of development environment

To evaluate the development environment of the chosen research environment with regard to the extent to which the success factors in the literature stated in section 2.1 are addressed, eight qualitative interviews were conducted. This also served as evaluation of the success factors to answer research question 1. The participants of the interviews covered the roles product developer, scrum master and product owner. For the evaluation, the success factors of the various authors were clustered in different dimensions to enable a qualitative assessment of the factors. Therefore, they were asked to confirm or deny the respective success factor and in addition, a brief description of their experience in the research environment weather the success factors are already addressed or not should be given.

Success factors under the dimension of technology like technology availability, same IT infrastructure and communication technology can be confirmed in the research environment. The IT infrastructure must be available and standardized, otherwise a pronounced communication is not possible. The cluster of communication with the components intensive communication and quality of communication is expressed by developers in the way that a culture of intensive communication must be developed within the company so that knowledge is distributed among different knowledge carriers, synergy effects are created, and errors and problems are identified early on. The value of trust like learning to work together and relationships with in the team is highlighted by interview partners as the importance to learn to trust team members working at different locations to work together towards a common goal. In the same direction the success factors of a clear top management support with a specified management strategy and purpose of the team are validated as the employees state that the top management should set clear goals so that the purpose of the team is understood by all involved. If the top management supports the mission, it is much easier to get support from colleagues. For the success factor of proactivity of team members, it can be concluded that it is important for the team members to learn to take more personal responsibility and to deal openly with their own mistakes and those of others. In addition, problems must be communicated proactively and asked for help. Also, task scheduling and a harmonized development process are seen as relevant. For example, it is important to have a clear formulation of the user stories and the elements of the development process. Apart from that the opinion that the integration of team members from different organizations enables new perspectives has not been confirmed. New perspectives can bring advantages, but from experience of the experts, trans-organizational teams often lead to an outranging number of disadvantages due to different standards and different disciplinary assignments. In conclusion, all success factors that could be confirmed through interviewing team members of distributed teams are related to the broad topic of communication and therefore need to be addressed in the development of a methodical support.

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5.2. Assessment of improvement potentials

To identify improvement potentials of communication, eight semi-structured guideline interviews as the method for process step 2A are conducted with employees from different Scrum roles and different locations. Therefore, the following four guiding questions were discussed with every participant:

- How do you feel in general about distributed product development?
- In your opinion, why is our company working at different locations?
- In your opinion, what is particularly important for successful distributed product development?
- Where do you see potentials in communication processes of distributed product development?

Through these interviews improvement potentials in communication processes of distributed product development in the research environment are derived concerning...
... late start of meetings.
... time loss due to audio and video connection issues.
... lack of consideration for colleagues who have connection problems.
... poor audio quality.
... poor comprehensibility of many people in large rooms.
... an incomplete communication due to missing facial expressions and gestures without video broadcast.
... missing possibilities to initiate spontaneous video conferences.
... a missing overview of all participants of the meeting.
... a lack of knowledge about the use of existing technology due to the diversity of technology systems.

Following, the impacts of the identified potentials are identified and prioritized based on a quantitative survey divided into two parts with 34 developers from six different teams as method for process step 2B. In a first step, based on the identified potentials from process step 2A, the participants where asked for impacts of the respective potentials. In the following step, the developers needed to rate their agreement to each statement from step 1 based on a Likert scale from 1 (strongly agree) to 5 (strongly disagree).
As a result, the top three impacts of the identified potentials in communication processes of distributed product development with the highest degree of agreement are shown in Figure 2. As presented, frustration arises, meetings become stressful and still 50 percent of the participants agree that the quality of results in meetings is reduced due to connection issues.

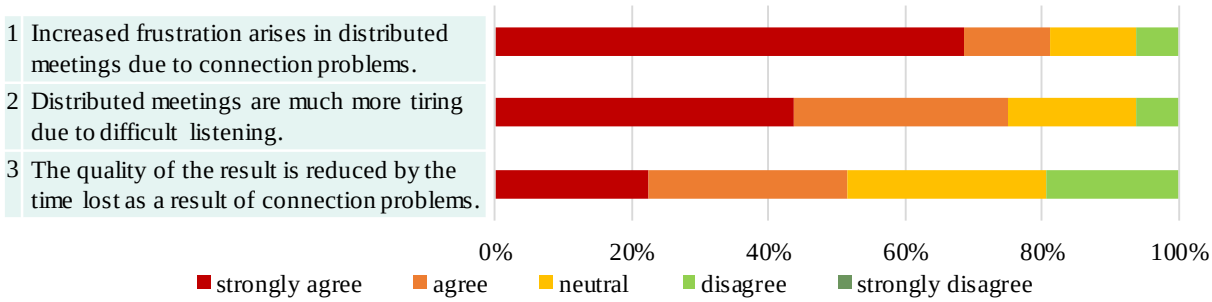

Figure 2. Top 3 soft impacts on distributed meetings

Since such soft effects often have little effect on management decisions in more traditional environments, in the second part of the survey, the calculation of monetary effects of the potentials is considered. The participants evaluated statements derived from the identified potentials as results from process step 2A. This took place based on a procedure inspired by the failure mode and effects analysis (FMEA) with the following three questions in accordance with the work of Müller et al. (2017).

- How often do you face the following situations? (frequency)
- How much time is lost on average due to the following situation? (temporal significance)
- How many people on average are affected by the situation? (personnel significance)

A multiplication of the mean values of the respective answers provides a potential for improvement measured as a time value. By including an internal average salary, the monetary loss can be explicitly represented. The presentation of the figures offers the company management the opportunity to argue regarding budget releases for corresponding technological purchases as well as employee training.

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In Figure 3, the evaluation of the monetary part of the survey is shown for the study environment standardized to the greatest potential. The greatest potential here is offered by the improvement of audio quality in large meeting rooms, followed by the general improvement of audio quality. Thus, the analysis offers the possibility to objectively demonstrate the priority of measures.

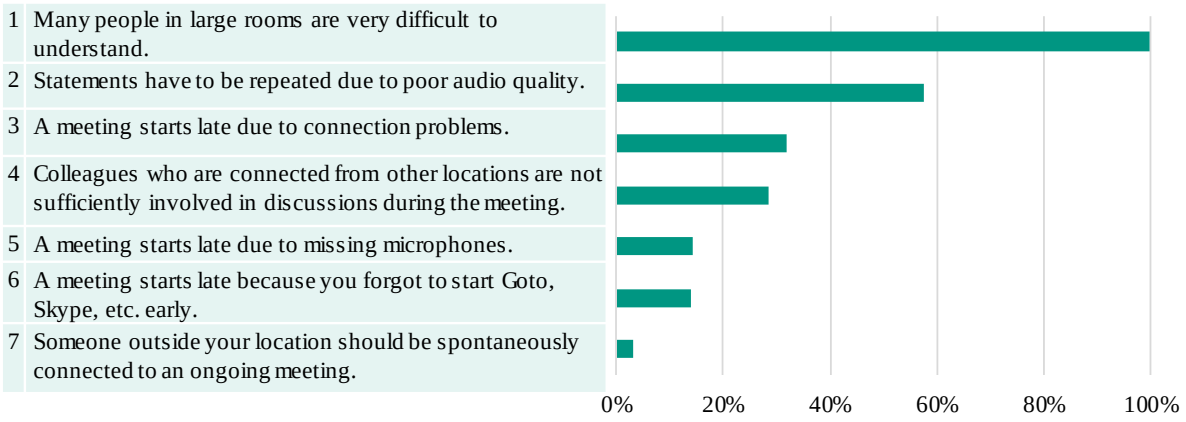

Figure 3. Monetary improvement potential in the research environment

5.3. Identification and implementation of measures

Based on the prioritization of the improvement potentials, measures could be derived and prioritized with the involvement of the employees in a workshop (process step 3B and 3C). In the workshop, the eight participants were encouraged to develop new measures and to cluster them in relation to the TOP model and to prioritize them afterwards. The direct reference to the three dimensions technology, organization and people ensures a holistic design of the measures.

Measures that have been developed in the workshop and were implemented in the research environment (process step 3E) include fully digital execution of dailies from the workplace, organizing a joint physical meeting of a distributed team, distribute cards with communication rules in meeting rooms and improving audio quality in large rooms by implementing and introducing interactive technology like a throwable microphone, so called CatchBox.

In order to validate and demonstrate the effectiveness of these measures (process step 3F), the evaluation of the identified improvement potentials took place. As an example to address the identified improvement potential of audio quality in large meeting rooms, a CatchBox (throwable foam cube with an integrated microphone and transmitter) was used in distributed meetings. 16 participants of the distributed meeting evaluated the implementation of the CatchBox by rating the given statements on a five step Likert scale (shown in Figure 4). The evaluation provides a very divided picture. Since more than 50% of 16 participants still rate the CatchBox as positive in the last question, its use is considered a success. As feedback from the participants, it was stated that the CatchBox helped to avoid confusion in discussions and in general communication rules for distributed meetings should be enforced.

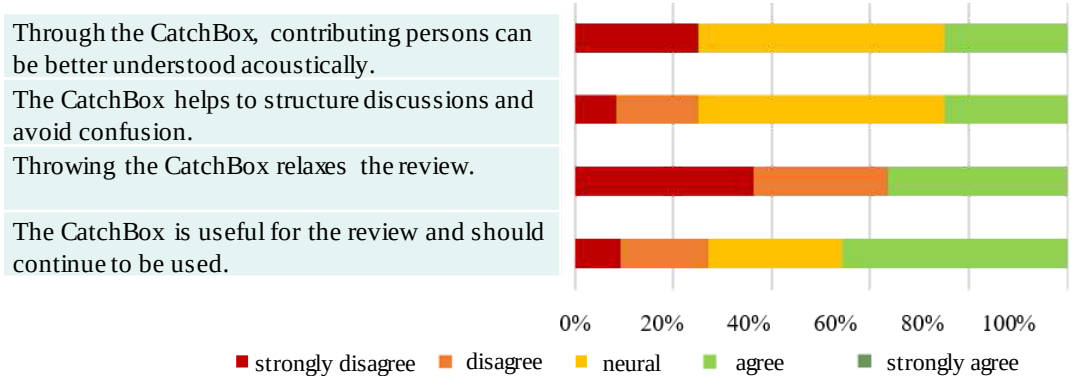

Figure 4. Evaluation of the CatchBox used in distributed meetings

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6. Discussion, conclusion and outlook

In summary, it can be stated that communication is currently the essential aspect of distributed product development in the considered research environment. Regarding this, most of the success factors found in the literature were confirmed. Since the identification and addressing of potentials in communication processes of distributed product development is considered a problem-solving process in this publication, a suitable reference process, the SPALTEN process, was identified. However, a comparison to other approaches that consider the identification of potentials and measures is missing. This will be subject of further research activities. The initial approach of this publication so far only addresses the individual process steps that are necessary to achieve the goal. The validation of the process steps in the research environment showed that there are several methods with which the individual steps can be implemented. Unfortunately, there are no reference methods for this so far. The methods for the individual process steps were therefore selected and implemented after reviewing the existing development environment. In the last step of the validation, it was shown that the implementation of measures can only be successful if the measures are identified under the awareness of the TOP dimensions technology, organization and the people. Therefore the dimensions have to be integrated at each step of the methodology. This should be taken into account in more detail in the next steps. In addition, it has become apparent that for some measures a more in-depth sharpening of the measure is necessary before implementation.

Concluding, the structure of the approach as a modular system of different process steps is particularly useful for a development environment were employees are familiar with agile principles and can thus always help to determine the direction in which they want to improve their work situation in distributed product development. A validation of the process steps of the modular applicable methodology in a first preliminary study verified the successful application and showed that over 80% of the employees have increased frustration due to connection problems in distributed meetings. The biggest improvement potential for the research environment was the improvement of audio quality in large rooms.

The next step to achieve the overall long-term research goal is to extend the modular approach consisting of several process steps with methods how each process steps can be carried out. Therefore, the integration of the TOP dimensions need to be considered holistically. In addition, the approach must be enhanced by a concrete and as well modular applicable catalogue of measures identified from literature and assigned to the TOP dimensions to support the process of identifying measures. Furthermore, during some workshops it turned out that the low level of efficiency of some distributed activities led to the assessment that not all development activities were equally suitable for distributed execution. This observation will be investigated in the following research activities. Eventually, a modular approach of process steps, respective methods and measures will result to increase the efficiency of communication in distributed product development.

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