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TITLE

Success factors of an IPD based approach in a remote multidisciplinary team environment - Reflections on a case study

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ABSTRACT

Integrated Product Development (IPD) is comprehensively discussed in literature. The human-centered approach offers a parallelized set of work activities in interdisciplinary teams. Due to the rapid globalization of IPD activities in the companies, project members are often obliged to work remotely in teams and through virtual means of communication. However, with the recent shift towards working remotely in IPD teams new challenges have emerged that might adversely affect the success of IPD projects. The objective of the paper is to outline the key factors strengthening and weakening the IPD process in a remote multidisciplinary team environment. To fulfill the objective, a case study on an international multidisciplinary team of postgraduate students working on a design project with an IPD approach, was conducted. The results highlight key success factors and their contributions to the project success in a remote multidisciplinary team environment. Additionally, key weaknesses of such approach and their negative impacts are also indicated.

KEY WORDS

Integrated product development, Collaborative design, Teamwork, Design education, Case study

1 INTRODUCTION

Product development in dynamic markets challenges existing engineering methodology as well as collaboration in multidisciplinary teams. Due to limited resources, product development projects are shortened by means of IT support (PDM/PLM) or concurrent engineering. Increasing quality of results as well as better resource-efficiency in product development are targeted by integrated product development (IPD). Remote collaboration in IPD challenges existing education of both, students and practitioners. Within this paper challenges and opportunities towards education of students and industrial practitioners in an IPD context are derived from a case study.

This paper is based on experiences of a case study as part of an International Summer School (ipdISS) for postgraduate students. Within the four months of case study, participants experienced a practical product development scenario.

Though all participants were trained in the overall IPD methodology and relevant methods, practical experience revealed further strengths and weaknesses with positive and negative impact on project success.

Consequently, this case study has three main objectives. The first one is to provide guidance and recommendations for young practitioners and researchers that have to handle several product life issues during one product development project in an integrated way.

Secondly, this contribution provides an example of collaboration in an international and multidisciplinary team working in distance on product design and development. Academic literature presents many research regarding either multidisciplinary or virtual collaboration on an international level. However, these aspects do not exclude one another. For this reason, this research aims to describe the strengths and the challenges that happens in the working environment that has been mentioned and to compare such results with the one present in the literature.

As a third objective, implications for future IPD education are derived. These founded on identified key factors strengthening and weakening an IPD process in a remote multidisciplinary team environment.

In section 2, the state of the art for both, IPD and multidisciplinary working groups as well as remote collaboration is presented. Research methodology and task of the case study is described in section 3. The working process with regard to both, resulting product and project organisation is outlined in the following. Based on these results, implications for future IPD projects and IPD education is derived in section 5.

2 STATE OF THE ART IN PRODUCT DEVELOPMENT

As previously mentioned, this research is more focused on project challenges and success factors rather than the product or its development process itself. Literature review is divided into two sections: the first part of the literature review, in sub-section 2.1, focuses on the integrated product development (IPD) approach used to develop the product; the second part addresses the characteristics of the working team, related challenges and success factors are outlined in sub-sections 2.2 and 2.3.

2.1 Integrated Product Development (IPD)

Various process models for IPD have been developed based on the initial approach published by Olson and other authors in 1981 (Vajna 2014). Olson's approach is focused on a parallelized set of activities carried out by an interdisciplinary team from various departments of an enterprise (Vajna 2014, Olson 1985). Olson's process model is characterized by four parallel sets of activities - marketing, development and production as well as activities concerning project management and economic feasibility.

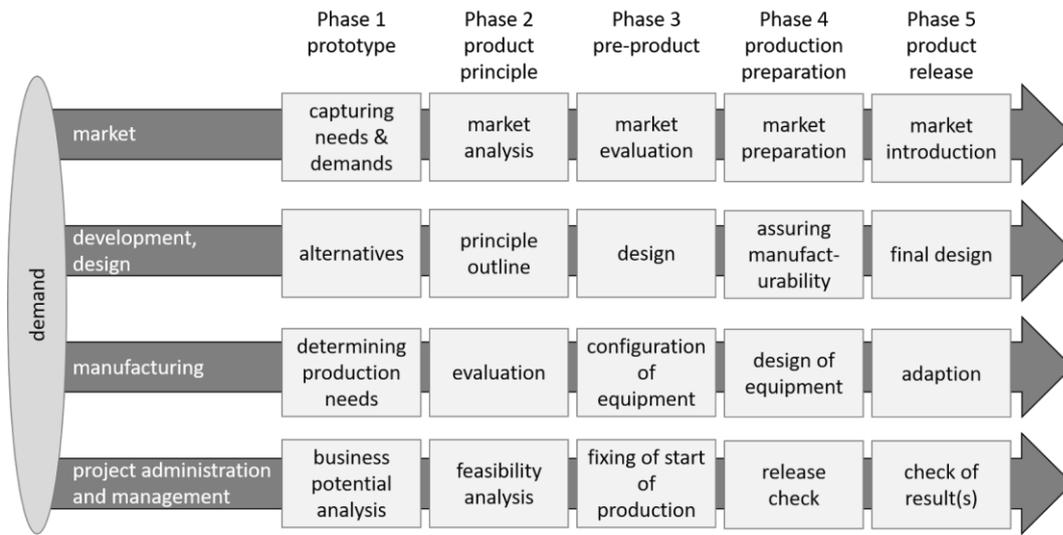


Figure 1. Initial IPD Model (Olson 1985)

The process model developed by Andreasen in 1987 (Andreasen and Hein, 1987) does not include the latter set of activities (Vajna, 2014). Further process models have been developed in Germany by Meerkam and Vajna. Meerkam's approach is linked to the trade-off between time, cost and quality aspects (Ehrlenspiel and Meerkam, 2013). Key aspects of this concept are organization, technique, methodology and human capital (Meerkam, 1994). The IPD-approach outlined by Vajna and Burchard (Burchard, 2001, Vajna, 2014) is an evolutionary human-centered process model combining the parallelized set of activities from Olson and Andreasen, the methodology from Meerkam's approach and the dynamics of development processes as outlines by Ottosson (Ottosson, 1996) (Vajna, 2014). The IPD-approach proposed by Vajna has been extended to cover aspects of product lifecycle management, sustainable and economic product development and entitled the integrated design engineering (IDE) approach (Vajna, 2014). Success factors for IPD projects have been widely investigated. These include governance elements, such as portfolio and resource management, as well as cross-functional knowledge management (Sommer et al., 2014). Haque (2003) reports a set of success factors which are strongly interrelated: effective teams, process understanding, IPD awareness and process modeling and analysis. Success factors for working in multidisciplinary working groups are - in a general context - outlined in the following section.

2.2 Multidisciplinary Working Group

Work of a multidisciplinary team is described by Carrier and Kendall (1995) as 'a group of people with complementary skills who are committed to a common purpose, performance goals, and approach, for which they hold themselves mutually accountable.' Therefore, multidisciplinary teams convey many benefits to both system improvements and collaboration between stakeholders. In fact, according to Collado-Ruiz et al. (2010) 'trans-disciplinary' is a key success factor in new product development. However, 'putting people together in groups representing many disciplines does not necessarily guarantee the development of a shared understanding' (Clark, 1993).

A research by Van Der Vegt and Bunderson (2005) demonstrates that both high levels and low levels of expertise diversity usually lead to a limited team performance, regardless of how much every member felt part of the team (collective team identification); moderate diversity in the expertise of the team members as a factor increasing the success of the team is suggested by this study. Another conclusion is that external communication is relevant for the team learning in a multidisciplinary team, but highest benefits are realised when the team generates ideas through intra-team efforts where members fuel each other with new insights. This conclusion is quite aligned with the result of a research by Vissers and Dankbaar (2002) about creativity in multidisciplinary NPD teams. A study by Gebert et al. (2006) shows that teams working on cross-functional new product development (NPD) do not always bring innovation and effectiveness of results is not always high. However, the authors conclude that in order to obtain potentially more positive outcomes two aspects are of central importance: (i) differentiation of relationship and value conflicts from task conflicts and (ii) 'social categorizations, as well as consolidated thought worlds, need to be separated from cross-functionality.'

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Recently, a new system for implementing formalized multidisciplinary collaboration in product conceptual design process was proposed by Yan et al. (2016). Yet, the proposed method is designed for larger working groups, and requires a formalized representation of product conceptual design.

2.3 International & Virtual Collaboration on Product Development

According to Ale Ebrahim et al. (2009) the most widely accepted definition of virtual team is the one proposed by Powell et al. (2004): 'we define virtual teams as groups of geographically, organizationally and/or time dispersed workers brought together by information technologies to accomplish one or more organization tasks.' A list of 35 advantages and 12 disadvantages associated with virtual teaming is set up by Ale Ebrahim et al. (2009). Main assets are reduced relocation time and costs, reduced travel costs, or greater degree of freedom to individuals involved in the project development. Disadvantages associated with virtual teaming are vulnerability to mistrust, communication breakdowns, or challenges in managing conflict. McDonough et al. (2001) distinguish behavioral and project management challenges that may affect collocated, virtual and global NPD teams. Virtual and global teams may be more subjected to these challenges compared to collocated teams. However, this typology of teams (virtual and global) is going to be increasingly used since they require less economical efforts. In order to anticipate related challenges and to support the product development efforts, training of managers and improvement of organisational infrastructure should be conducted. Tavčar et al. (2005) provide a set of recommendations on how to develop necessary skills for effective communication and work in virtual development teams. Based on an international product development course, called E-GPR, nine requirements for effective work in virtual teams working on product development were defined and could be used as recommendations to follow in our project. The main advantage for our case is that these recommendations can be applied in both university and industrial environments. Recommendations encompass not only effectiveness, creativity or communication in a virtual team but also conflict resolution. More recently, Chae (2016) highlights the importance of elements such as perceived proximity and trust network in the performance of remote team. Eventually, online platforms and tools are increasingly available to facilitate efficient virtual collaboration. For instance, shared file storage and synchronized system, such as Google Drive, is a virtual environment that allows real-time multi-user collaboration by team members in different physical locations.

3 RESEARCH METHODOLOGY & CASE DESCRIPTION

A case study is a preferred scientific research method to closely investigate and understand a specific phenomenon within its natural context (Eisenhardt, 1989; Yin, 2011).

The findings of the paper are based on the outcomes of an IPD project offered in an IPD training course for postgraduate students. In this course, which extended over four months, a group of seven postgraduate students participated. Participants of the course were asked to develop a 'Human Washing Device' using an IPD approach. The project team consisted of seven participants of five different nationalities with different backgrounds in Business Management, Cost Engineering, Mechanical and Eco Design, Industrial Engineering, and Lifecycle Assessment. The participants were remotely located in- and outside of Europe. The developed device aims to support elderly people in washing themselves. Required system properties are:

- Adjustable according to different body sizes
- Modular and available in variants for use in elderly care centers as well as domestic applications
- Usable in sitting and standing positions
- Low water and energy consumption
- Having positive emotional design
- Compliance with Health & Safety regulations

Expected results included a product concept, a developed 3D-model, a mock-up as well as a manufacturing and a business concept. The former included all make-or-buy-decisions, the latter consisted of a business plan, a detailed investment plan as well as a marketing concept including advertisement. Remote collaboration was compulsory, because face to face meeting was only possible during the first week (project kick-off) and the last week (result presentation) of the course.

Good case studies benefit from multiple sources of evidence namely: direct observation, interviews, archival records, documents, participant observation and physical artefacts (Yin, 2011). In the

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presented case study, project documents and participant observations have been the main sources of data collection. Project documents included the minutes of meetings, E-mails, and presentations that were made during the course of this project. Additionally, observations were made by all team members during the 26 working meetings which were focused on the different aspects of the project according to the project plan. The data analysis was on-going during and after the data collection by making categories and developing them, developing propositions for categories and drawing conclusions, as suggested by Saunders et al. (2012). Following the completion of the project, a face-to-face lessons learned session was held through which the reflections of all team members regarding strengths and weaknesses of the working process were collected. All participants were asked to individually select the three success factors with the most fundamental impact on project success. In addition, the three weaknesses with the most critical negative impact on the project success were individually selected from the above list of strengths and weaknesses. The weighted impact is the aggregation of the number of occurrences among the case study participants. Results are discussed in the following section.

4 CASE STUDY FINDINGS

4.1 Work organization

In the beginning and during the first week of the course, the project group was formed. As agreed upon by the team members, a detailed project plan and project risks table were developed. Accordingly, due to the international and distributed nature of the project team, means of communication and document sharing were decided upon.

4.1.1 Project plan

The initially developed project plan included seven main activities and 63 sub activities. The seven main activities were: state of the art research, customer needs research, concept initiation and evaluation, product design, prototyping, business and market research, and documentation. In the initial project plan, activities, progress status and deliverables were defined. In addition, for each activity four different roles were defined to indicate the involved resources for performing each activity. The four defined roles were as follows:

- Responsible: coordinating and working with the activity
- Accountable: working with the activity
- Informed: being informed about the activity
- Consulted: supporting the activity if needed

Project activities and different roles were assigned to each team member according to their previous experiences and potentials. In each main activity, one team member was chosen to have the responsible role.

4.1.2 Communication and document sharing

Considering the international and distributed nature of the project team, the impossibility in meeting in person, and the privacy restrictions, Skype for Business was chosen as the most appropriate environment for virtual communication to hold weekly project meetings. During the five months of the project in total, 26 working meetings were held including 18 weekly meetings, 6 manufacturing discussions, 1 creativity session, and 1 customer definition meeting. In the weekly meetings, the issues regarding different aspects of the project and according to the project plan were discussed.

Moreover, Google Drive was chosen as the platform for sharing and uploading different documents of the project. Accordingly, different folders were defined and team members had access to review, modify and upload documents. These included specifications, concept sketches and CAD-models as well as manufacturing documents and the business plan for the device described in the following.

4.2 Case study results - Human Washing Device

Based on the creativity session and further discussion, usage of a combination of a stationary washing device and a handheld scrubbing shower head was developed. The first device is stationary installed in the shower cubicle. Fitting into various cubicle sizes and installable in both, existing and newly-built environments, modularity and complexity reduction were major challenges to be faced within the

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development. The device consisted of a frame with a height-variable rotating sponge tissue for cleaning. By connection to the water supply in the shower and an automatic dispenser of soap and cleaning fluid, the solution acts as a semi-automatic device. Compliance to hygienic standards and easy cleaning of the system are ensured by an automatized dispersion of disinfectant to the sponge tissue. Dependent on the use case (home use or professional use in retirement homes or hospitals) either multi-use or single-use tissues can be attached to the system. Different types of tissues (according to softness etc.) were developed for an individual experience. The second device acts as a complementary device for body regions not being reachable by the stationary device. Concept sketches and a CAD-model are shown in figure 2.

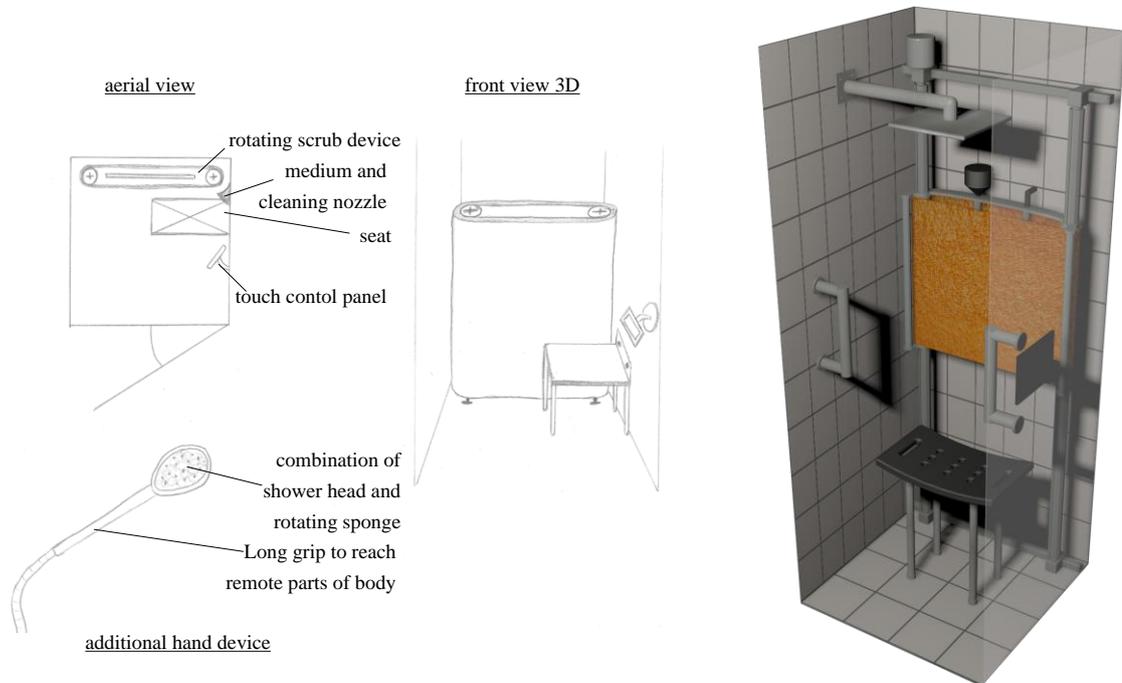


Figure 2. Concept sketch (left) and final CAD model (right) of case study result: The Human Washing Device

4.3 Reflections on the case study

Despite the development of the product itself, reflections on the project were gathered. In a lessons learned session, performed after the project was completed, all participants evaluated strengths and weaknesses of the work process and environment. As weakness the low communication due to no physical meetings and the variation of participation in the virtual meetings was mentioned. As a result the competence of individuals was not totally exploited. In addition, especially the virtual idea finding and the selection of ideas was criticized.

The general multidisciplinary environment was reviewed as a strength. The high reactivity, flexibility and strong tendency to collaborate was lauded. A structured planning in the kick-off phase resulted finally in a reasonable product which meets the requirements and was delivered in time. The project results included all three IPD perspectives: the product itself as well as the business (business model and price calculation) and the manufacturing perspective (production concept and bill of material).

All main strengths and weaknesses collected by the case study participants are shown in table 1 below:

Table 1: Strengths and weaknesses collected by case study participants

Strengths		Weaknesses	
Description	Weighted impact	Description	Weighted impact
- Multidisciplinary environment	3	- Lack of capability for time management	0
- High reactivity on occurring problems	3	- Lack of integrated selection of ideas	5
- Flexibility	5	- Lack of non-physical meeting	0
- Strong tendency to collaborate	1	- Low communication	4
- Structured planning	2	- Virtual idea findings	0
- Everyone had overview about project status	0	- Variation in participation	0
- Reliability of participants	0	- Documentation	0
- Product functions	0	- Competence of individual not totally exploited	2
- Time delivery of results and inputs	0	- Lack of motivation / missed chance to create motivating team atmosphere at kick-off	4
- Regular meetings	0	- Unavailability and relocation of resources	0
- Shared project data and records	0	- Use of a second language (English) for communication	0
- Task allocation	0	- Lack of certain needed skills within the resources	0
- Various problem solving approaches	0	- Lack of efficiency (in meetings and in individual work)	2

Thirteen strengths and thirteen weaknesses were mentioned by the case study participants. The strengths and weaknesses were collected and made visible to all participants. The weighted impact score is a result of an independent and anonymous survey. In that survey, every participant was asked to individually and anonymously select three strengths and three weaknesses with the - to his personal perspective - most fundamental impact on the project. Results of that survey were then collected and are displayed in table 1. The weighted impact is the number of how often participants mentioned the strength or weakness as one of their three most fundamental strengths or weaknesses.

5 RECOMMENDATIONS & DISCUSSION

As outlined in section 4, the participants mentioned thirteen major strengths and weaknesses. After the assessment of the weighted impact, five major strength and weaknesses have been investigated. Both were sorted according to their impact. Condensed results from the survey are shown in figure 3 below:

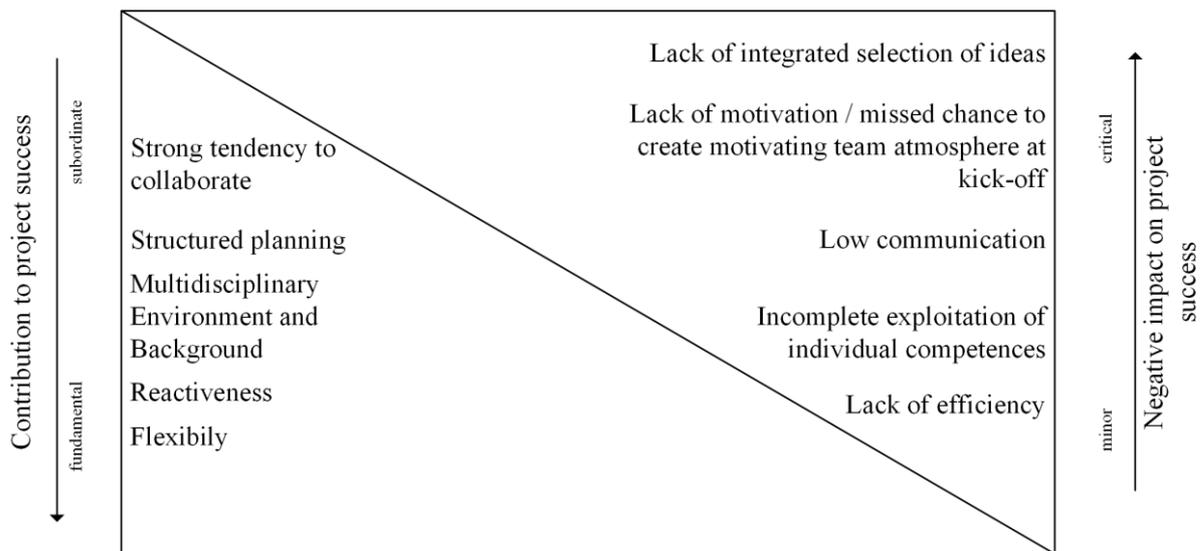


Figure 3. Key success factors and their contribution to the project success and key weaknesses and their negative impact

Reactiveness and flexibility were considered the most fundamental levers for the success of the project. The multidisciplinary environment and background of the participants, the structured panning and the strong tendency to collaborate were outlined as further levers with subordinate contribution to the project success.

In contrast, the lack of an integrated selection of ideas and a lack of motivation, probably resulting from the missed chance to perform team building activities at the project kick-off, were considered as most negative with regard to the project success. Further, low communication, an incomplete exploitation of individual competencies and lack of efficiency were investigated as minor weaknesses with the regard to the project success.

The major weaknesses of the lack of an integrated selection of ideas is strongly related to the results of *Visser and Dankbaar (2002)* and *Van Der Vegt and Bunderson (2005)*. Due to the virtual remote collaboration, the intra-team efforts to generate new ideas were lacking in this case study. The negative impact of low communication in the case study presented aligns to the result of *Ebrahim et al. (2009)*. On the other side, the main levers for the project success such as the multidisciplinary background and environment investigated within the case study is in line with the results from the literature (*Collado-Ruiz, 2010, Gebert et al., 2006*). Concerning the impacts identified as the most relevant for the project success - reactiveness and flexibility - existing procedures for IPD development such as the model by *Olson (Olson, 1985)* are challenged. From the participants' perspective, the sequential approach of *Olson* did not represent the actual procedure within the project. Though for product development itself, the engineering methodology of *VDI 2221 (VDI, 1993)* was chosen, approach realized and applied within the project was more related to an agile procedure such as *scrum*.

For future IPD training, capabilities for remote collaboration in multidisciplinary environments have to be extended. Students have to be trained to work in such environments. The impact of team dynamics (related to all negative impacts except the integrated selection of ideas) has to be considered in future IPD training. For students working in a remote IPD project, awareness and knowledge in this field has to be created to outcome weaknesses outlined in the IPD project presented. Strategies and means for overcoming these weaknesses have to - on a generic level - be incorporated in IPD training. For future IPD work, ideation has to be improved to suit the needs of remote collaboration. Agile approaches such as *scrum* seem to be more promising than other (conventional) engineering methodologies. The lack of ideation and idea selection in the presented case study, in line with other studies, challenges the existing creativity methods and ways of remote collaboration in the field of ideation. In remote interdisciplinary teams, the support of ideation by adapted creativity methods is even more important than in a non-remote collaboration. Despite the development of these methods itself, IPD training has to target the development of competencies in the field of ideation in remote working environments. Such a training may include both, facilitating tools for remote collaboration as

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well as competencies regarding the choice of ideation methods and creativity techniques for IPD projects in remote environments.

6 CONCLUSION

Within this paper, results of a case study among postgraduate students were presented. The case study - development of a human washing device for elderly people in an IPD context revealed relevant insights and implications in different perspectives.

At first, challenges and opportunities of collaboration in an international, multidisciplinary remote team working during design and development of a product were gathered by the participants

Secondly, another important conclusion derived is the fact that during the four months of activities participants managed to move from a multidisciplinary to an interdisciplinary environment. In fact, the different members of the team started with a deep understanding of their field of knowledge, but a scarce ability to connect it to other members' domain. However, every member learnt to empower their own areas of expertise with the knowledge from a different domain. Most of the team members, in fact, managed to enrich their knowledge and their abilities to cope with complex problems that needed a deep understanding of the tasks at hand; this would have been not possible without an interdisciplinary environment.

Overall, implications for future IPD education were derived from both perspectives mentioned above. IPD education has to aim at overcoming the identified weaknesses with the most negative impact on the project success (idea selection, lack of motivation, low communication, incomplete exploitation of individual competencies and lack of efficiency). The interdisciplinary working environment fostered by IPD projects has to be a core competency conveyed in future IPD education. Education about creativity methods in remote collaboration is required for a successful ideation in remote working environments.

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