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A Role-based Prototyping Approach for Human-Centred Design in Fuzzy Front-End Scenarios

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Abstract

This paper addresses the need for novel formats in engineering education that prepare students to work in increasingly volatile, uncertain, complex, ambiguous environments by promoting innovation and entrepreneurship. Students of the course Think.Make.Start. at TU Munich are motivated to work on real problems and explore the potential of new technologies or challenges by developing new solutions, while developing their skills as entrepreneurs. Different philosophies like Design Thinking, Lean, Agile and Prototyping have been combined and tailored into a novel approach that makes these philosophies easy and accessible for students who do not have prior knowledge of such design methods. The course is mainly about the development of mechatronic products. This paper proposes a new role-based approach based on prototyping, that helps interdisciplinary teams. Following the example of Stanford's Design Thinking course ME310, a role-based prototyping approach was designed and tested. The entire process places an emphasis on autonomy, innovation and peer dynamics. The application process was overhauled and a new process with an emphasis on learning-by-doing was deployed. The selection was role-based, and peer evaluated, thereby providing a platform for the students to to get to know their peers and gauge competition beforehand. The new methodology emphasizes autonomy and proactivity of the students and gives them the freedom they need for the development project. The new method emphasizes the prototyping process and places prototypes as measure of progress, through what we call the prototyping lens. It guides the students on important aspects of fuzzy-front product development by providing a template of the overall process and specific tools such as the prototyping planner. The method guides the students through the fuzzy front-end of new product development using tools that emphasize on slow integration of artifacts via micro logic that gets progressively complex with added methods and guidelines on prototypes and sprints. Each team is guided through this process with the help of daily coaching sessions and their progress is tracked, recorded, and evaluated. The results are then discussed in detail with an outlook for the future.

Keywords: design education, prototyping, entrepreneurship, new product development, human centred design

1 Introduction

The importance of innovation and entrepreneurship reflects in increased productivity and the creation of jobs in a changing world. At the same time, these changes lead to a shift in the requirements towards future employee's profiles. These changes dominating future working environments are often referred to as VUCA (Bennett & Lemoine, 2014): Volatility, uncertainty, complexity, and ambiguity. An increasing demand is predicted for cognitive skills of future employees such as creativity, logical reasoning, and problem sensitivity to succeed in such environments (World Economic Forum, 2016).

Engineering Education – The Future Engineer
To prepare future engineers for challenges of the future, many Universities established different sorts of teaching approaches such as entrepreneurial approaches. Still, those entrepreneurial approaches are not established across all universities. Therefore, no standardized teaching concept exists on how to prepare future engineers yet, indicating a need within the engineering education community. The CDIO approach serves the systematic development of training programs for engineers (Crawley, Malmqvist, Lucas, & Brodeur, 2011). The approach aims to create an education that gives students a deep understanding of the technical basics and at the same time develops the necessary professional skills needed by future engineers. Technical knowledge is taught together with personal, interpersonal, and engineering skills during project-based courses. The core of the approach is the conception, design, implementation and operation of products, processes, and systems from the real world. Comparable to the CDIO, the Technical University of Munich (TUM) introduced additional elements to classical engineering education. A course of this kind is the makeathon Think.Make.Start. (TMS) that prepares students through entrepreneurial acting for VUCA contexts through New Product Development (NPD) projects. This course aims at students applying their domain-specific know-how in interdisciplinary teams to work on real-life problems and develop matching solutions by incrementally developing a product under the usage of agile methods, fostering an agile mindset (Böhmer, 2018).

TAF The Agile Framework – The TMS Methodology
The original methodology of TMS was called *TAF: The Agile Framework* (Hostettler, Böhmer, Lindemann, & Knoll, 2017). Its core principle, which the students would apply during the course, was reducing "uncertainty on relevant aspects of the product with limited time and resources" (Böhmer, 2018). This methodology is based on the human-centered design (HCD) principles of *desirability*, *feasibility* and *viability* to create artifacts in order to channel prototyping activities into valuable outputs (IDEO, 2015). The micro level of TAF is represented by the PDCA cycle, regulating the level of activities and referring to: Plan, Do, Check, and Act (Deming, 1989). The macro level of TAF is defined by three phases, allowing users to work through three PDCA cycles in a row: starting with a desirability cycle defining user needs, followed by a feasibility cycle deriving functional requirements, and ending with a viability cycle giving insights into potential markets (Hostettler et al., 2017). This logic represents an iterative approach to transform ideas into prototypes. Nevertheless, little measurable data exists on the effectiveness of this approach in engineering education (including TMS) and on the goal of teaching engineers on how to act in innovative environments.

ME310 – The role model for engineering education
Stanford's ME310, introduced in 1960s, is a three quarter year course in the field of applied innovation (Carleton & Leifer, 2009). The ME310 approach is based on Design Thinking. The macro level of ME310 is structured through prototype milestones (e.g. Funky Prototype) to

structure the process (Vetterli, Brenner, Uebernickel, & Berger, 2012) and is supported by methods of Design Thinking. ME310 provides a practical approach and a safe environment to learn the real challenges of innovation and New Product Development (NPD) resulting from dynamic and ambiguous factors, especially how to deal with ambiguity in the process. As ME310 is a simulation, it gives students a glimpse on how they might deal with these uncertainties in their future work (Carleton & Leifer, 2009).

New Product Development (NPD) – Navigating through the fuzzy-front End

NPD describes the transformation of ideas or opportunities into tangible and viable products (Trott, 2016). The practical processes associated with the NPD are complex and depend on various success factors, such as: industry, company size, type of product, organizational structures, team composition (Ernst, 2002) as well as product strategy, customer orientation, preliminary research, and customer feedback (Bhuiyan, 2011; Zirger & Maidique, 1990). Increasing technological progress, growing global market structures and the resulting high level of competition are forcing companies to rethink the way they develop new products (Takeuchi & Nonaka, 1986), demonstrating the relevance of new products for the future (Bhuiyan, 2011). Purely sequential product development processes were questioned and important criteria for the design of new products were defined, such as: multidisciplinary collaboration, self-organized teams, knowledge transfer and overlapping iterative development phases and others (Takeuchi & Nonaka, 1986). Literature extends the NPD Process with the preceding Fuzzy Front-End (FFE) and the subsequent Commercialization and speaks in the overall context of the innovation process, in which FFE is considered to be the largest leverage with improvement for potential (Koen et al., 2002). The FFE is characterized by activities prior to the formal and structured NPD process (Koen et al., 2002) and generally includes phases from idea generation to concept development and project evaluation (Bhuiyan, 2011). In the TMS context, this means that student teams try to find their way through the FFE as quickly as possible, then follow the NPD process and briefly think about commercialization.

Prototyping Planner – Fostering a Prototyping Mindset

It is evident that prototyping possesses a significant meaning in TMS with the TAF methodology, in ME310, as well as in other NPD processes (Carleton & Leifer, 2009; Hostettler et al., 2017). Prototyping is characterized by an iterative process where several prototypes and alternative concepts are tested which in turn leads to new questions or ideas before a final solution is found (Hallgrimsson, 2012; Otto & Wood, 2001). To support Prototyping Activities the Prototyping Planner was introduced helping both planning and execution of the prototyping process (Hansen, Jensen, Özkil, & Martins Pacheco, 2020). The PP can be found online[1].

Through an explorative study, this paper proposes a prototyping approach linked to a role-based model, supporting student teams, and proposing a formalized prototyping methodology. The following research questions are addressed: *(RQ1) How do novice teams embrace a formalized, goal-oriented approach to prototyping?* and *(RQ2) How does the adapted approach affect the prototyping activities?*

In Section II of this paper, the development and evolution of the TMS methodology are outlined, followed by its evaluation through a case study approach in Section III. The paper discusses the results and reveals insights and questions in the final Section IV.

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[1] www.prototypingplanner.com/ppV2

2 Methodology

2.1 Course Design

Think.Make.Start. (TMS) serves as the test-setting for this research. It is a 10-day makeathon for students of TUM to create new products with the goal to create social, economic or personal value for people outside of the organization. The students are provided with an infrastructure, a 400€ budget for project expenses and get access to a high-tech workshop for prototyping activities. Coaches support the student teams with methods and tools on business, NPD and technological feasibility. For this, an idea is iteratively transformed into a Minimum Viable Product (MVP), representing an early version of a product to get feedback from early adopters (Ries, 2011). A MVP needs to be desirable (i.e. fulfilling a user need), feasible (i.e. available resources) and viable (i.e. a validated business model with potential customers) (IDEO, 2015).

The common goal is the enabler for collaborative work between different disciplines in TMS. To ensure that the responsibilities are clearly split, three team roles are defined based on *desirability*, *feasibility* and *viability* (IDEO, 2015) (see Figure 2). The *Problem Expert* is responsible for *desirability* and *viability*. He engages with the user and customer to understand them and identifies needs. As he knows the user and customer perspective, he is responsible for MVP marketing while assessing financial pain points and potentials. The *Business Developer* is responsible for *feasibility* and *viability*. He conducts market and competitor analysis to identify potentials while being responsible for the business model. All aspects like financial aspects, development costs, organizational factors, laws and regulations must be considered while guaranteeing a sustainable cash flow based on the business model. The *Tech Developer* is responsible for *desirability* and *feasibility*. He matches solutions for the defined user needs by testing and iteratively improving towards the user's wishes. Scalability aspects from a technical perspective must be considered as well as costs on technical components, development and manufacturing of the MVP for the business model.

In order to get the right students, they need to apply for the roles described above. The selection of participants was complicated in the past, since people submitted motivation letters, CVs and grades transcripts. These tended to be quite monotonic and not very indicative of entrepreneurship potential, making the selection difficult (Koycheva & Hostettler, 2019). The application process was fundamentally changed to a peer-reviewed process. Students no longer apply with their curriculum vitae and motivation letter. Instead, all applicants must specify their preferred team role matching their skills by submitting a creative application in any form explaining why they should be selected for that role. Each applicant then receives ten randomly selected applications from their peers in the same role category for rating. Based on the average ratings, an overall ranking of all applications in the different team roles is created, serving as a basis for the selection of the 50 participants.

2.2 A Role-Based Prototyping Approach (RBPA)

A holistic framework for the *Role-based Prototyping Approach (RBPA)* is illustrated in Figure 1. The overall structure of the prototyping journey includes the team roles described in 2.1.

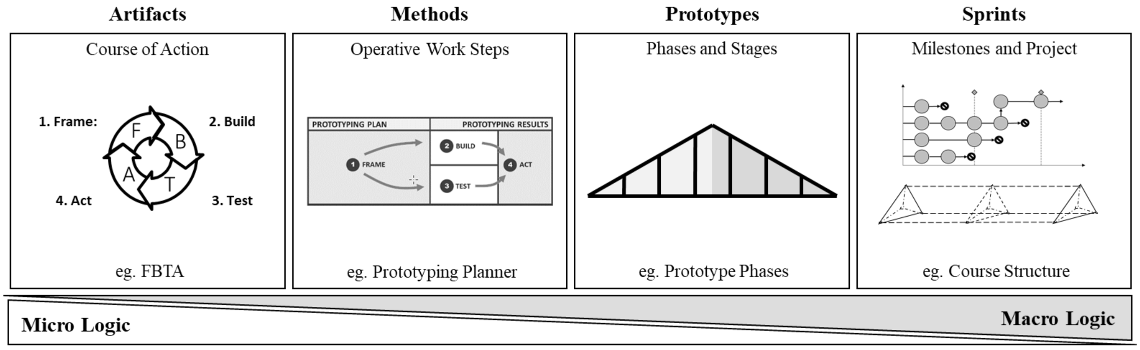


Figure 1. A holistic framework for the role-based prototyping approach (RBPA) of TMS consisting of a Micro and Macro Logic inspired by Böhmer (2018).

Inspired by Design Thinking, prototype phase milestones with divergent and convergent thinking are used to guide the teams through the prototyping journey, providing tangible goals and development structure (Uebernickel, Brenner, Pukall, Naef, & Schindlholzer, 2015; Ulrich & Eppinger, 2011; Vetterli et al., 2012). The methods and tools are not explicitly integrated in the approach as it aims at students being proactive when they face challenges. Additionally, *Frame*, *Build*, *Test*, and *Act* cycle (FBTA) supports students throughout the uncertain process from team to MVP (see Figure 2). The RBPA methodology is based on a variation of the Design Thinking model of ME310 (Uebernickel et al., 2015). It does not include a double diamond, instead it uses a single diamond approach. The prototyping phases of ME310 were adapted to the requirements of this study (See Figure 3).

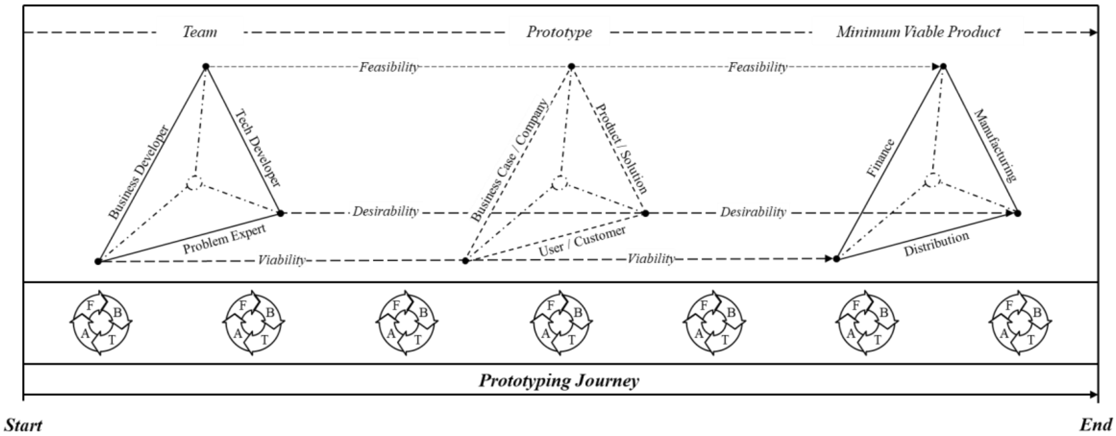


Figure 2. The Prototyping Journey from Team to Minimum Viable Product (MVP). The team roles work with respect to desirability, feasibility, and viability and undergo multiple iterations covering several aspects at a time. The insights lead to the incremental learnings allowing awareness about potential users and customers. Depending on the team, the nature of their idea, the available resources, the targeted user and customer among other factors, the team is guided towards the MVP.

The *Ideation Prototype* start the divergent phase and encourages teams to create quick and simple prototypes that assesses the potential of opportunities by visualization of ideas and by getting first insights on needs of potential customers and users. The *Critical Function Prototype* aims at transforming the identified ideas from insight into user functions to address a single user issue and test it. A deep understanding of the user’s need is generated and possibilities of realizing a fitting solution are checked beforehand. The *Out-of-the-box Prototype* encourages to change perspectives to think outside the box by checking ideas that were rejected earlier. The *Vision Prototype* marks the transition from the divergent into the convergent phase and aims to integrate promising elements from previous findings and giving a first visualization of a potential not technically working MVP. The *Proof-of-Concept Prototype* addresses the transformation of the *Vision Prototype* into deliverable features by visualizing a *looks*- and *work*-like model to use it for testing. The *Feature-ready Prototype* contains at least one fully developed critical feature from the *Proof-of-Concept Prototype*. *The Feature-Ready Prototype* gives the team an estimate on the remaining workload. The *Final Prototype* integrates all the insights from previous convergent phases into a single self-explanatory concept that early adopters would be willing to pay for, namely the MVP.

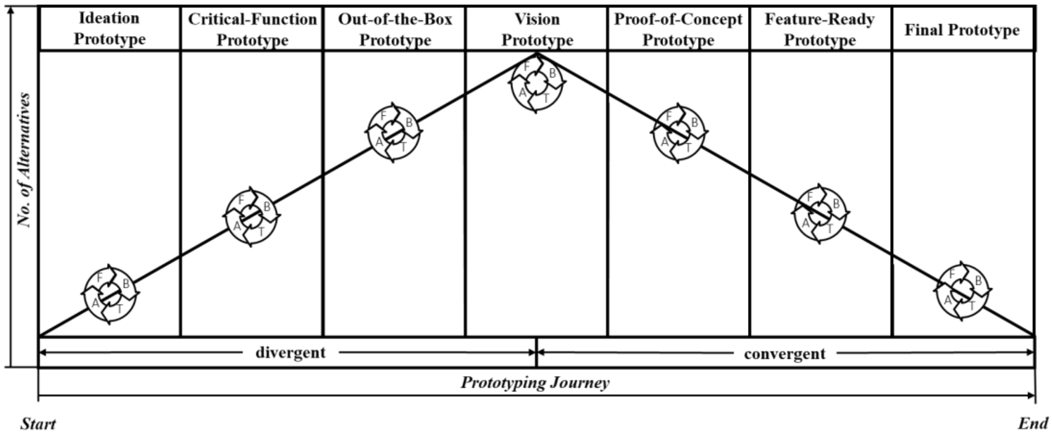


Figure 3. Prototype phase milestones are split into a divergent phase broadening the design space and a convergent phase combining previous insights into a single concept, in accordance with Vetterli et al. (2012).

A pivot might occur as a result of the insights a team collected from user testing. In that case, the team can return to any earlier phase. To support the prototyping approach a *FBTA cycle* is included on the operative level (Hansen et al., 2020) to guide the students throughout an ambiguous and dynamic prototyping process. For each prototyping activity, a cycle is completed, while *Frame* and *Build* define the prototyping activity, *Test* and *Act* are the result of the prototyping experiment.

2.3 *Deployment of the Methodology*

The methodology was deployed at the 10th iteration of TMS. It starts with a pre-event day that lets students get acquainted and find potential teammates creating a sense of community, while familiarizing with the practical approach, the goals for the event, and kicking-off the ideation based on general trends in society, technology, and economy. During the two weeks between the pre-event and the makeathon, the students observe and interact with their surroundings. Their observations are used to suggest possible work topics on a digital platform. One single input is given in the beginning of the makeathon about the approach. The day concludes with a structured ideation. Daily mandatory Q&A sessions with coaches with methodological and technological know-how are offered to support the teams in their daily session. Progress presentations with teams presenting their current progress to their peers are held every second day. The mid-term presentations for a few selected guests from industry and the demo day, an open event where the teams present their final products with over 300 guests, are the milestones and form the course structure.

Day one starts with an ideation based on the insights from the observations. *Ideation Prototypes* are quickly built to visualize and test desirable ideas. In this time the students familiarize with each other. They are given the task to build an *Ideation Prototype* for an idea and form a team. Teams require one *Business Developer*, one *Problem Expert*, and two to three *Tech Developer*. From day two to three the individual team progress is assessed and giving advices during the obligatory Q&A. The teams build *Critical Function Prototypes* between days two and three to understand and define the user evaluating their solutions for desirability and feasibility. The teams are then pushed to divergent thinking while building *Out-of-the-Box Prototypes*. The previous findings on user's need, matching solutions and potential markets are integrated into a *Vision Prototype* including a preliminary business model which is presented during the mid-term presentations. With the mid-term feedback, the teams are advised to build *Proof-of-Concept Prototype* to transform user needs into matching desirable and deliverable features. Depending on the individual progress, days seven to nine are used for *Feature-Ready Prototypes* deciding which features will be realized in the *Final Prototype*. Other features might be dropped or defined as a vision for the product. On the last day, the teams present one *Final Prototype* with a matching business model. Teams are allowed to split the *Final Prototype* into a *works-like* prototype to show functionalities and a *looks-like* prototype to communicate user benefits (Hallgrimsson, 2012). The final event serves the purpose to get feedback on the project in order to decide about a continuation of the project.

3 Evaluation

3.1 Selection Process – Team Roles

The course received 106 applications from various disciplines from TUM including 37 Problem Experts, 28 Business Developer and 39 Tech Developer. The best 10 Problem Experts, 10 Business Developer and 30 Tech Developer received admission. From 50 admitted students, 41 participated, including 8 Problem Experts, 10 Business Developer and 23 Tech Developer (see Table 1).

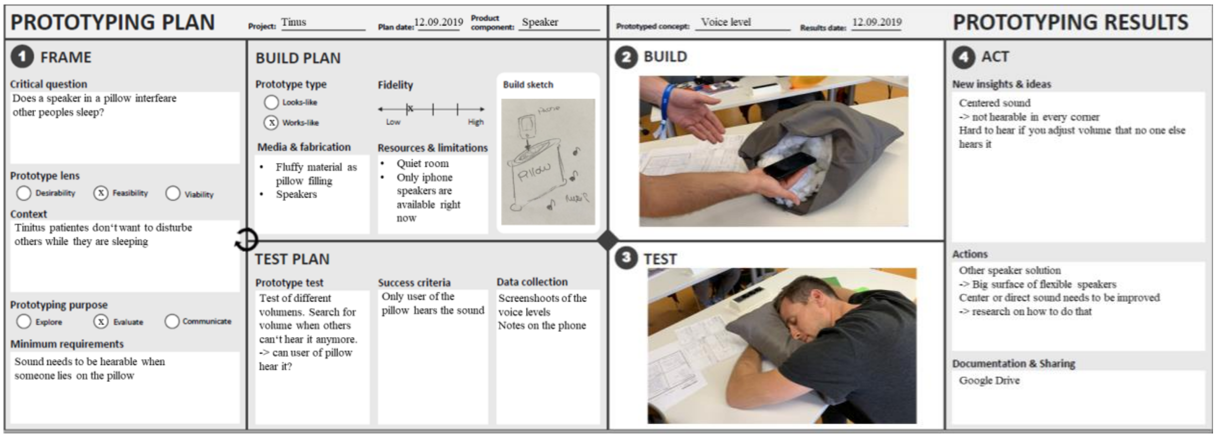
Table 1. Team composition. The teams formed independently eight interdisciplinary teams. Every team required a maximum of one Problem Expert, one Business Developer and two to three Tech Developer. An exception was made for two teams due to short-term participant cancelling.

	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7	Team 8	Sum
Problem Expert	1	1	1	1	1	1	1	1	8
Business Developer	1	1	1	1	2	1	2	1	10
Tech Developer	3	3	3	3	2	3	3	3	23
Sum	5	5	5	5	5	5	6	5	41

3.2 Case Analysis of Team 8

A case study on the prototyping process of team 8 is shown and analyzed below. The team consisted of one Problem Expert, one Business Developer and three Tech Developer.

The team carried out twelve prototyping activities and documented each accordingly (see Figure 4). 30% of the prototypes were built in the divergent phase and 70% of the prototypes were built as they rushed into the convergent (see Figure 5).



a) Planning of Prototyping Activity *b) Executing and Reflecting Prototyping Activity*

Figure 4. Prototyping Planner of Tinus (Example). A customized version of the Prototyping Planner was used to support the frame, built, test, and act cycle approach. First the prototyping activity is planned (a) and then executed and reflected (b). Each time a new prototyping activity was attempted a new Prototyping Planner was created.

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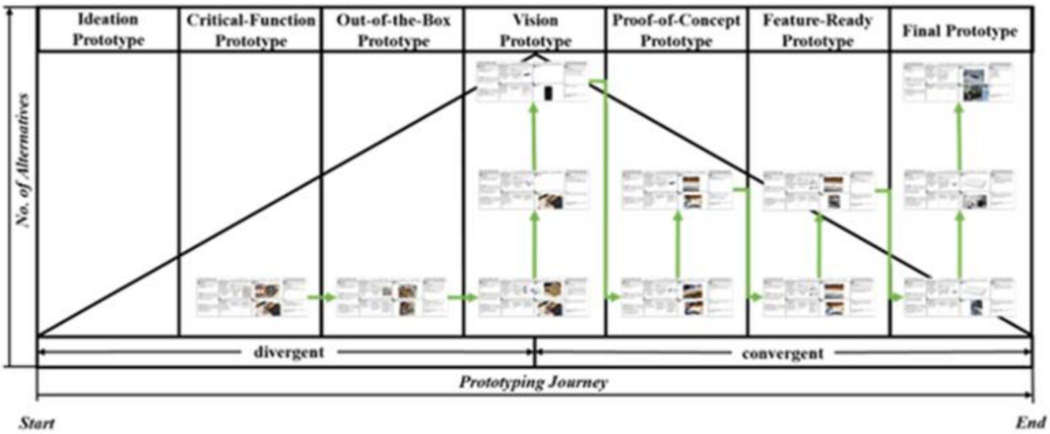
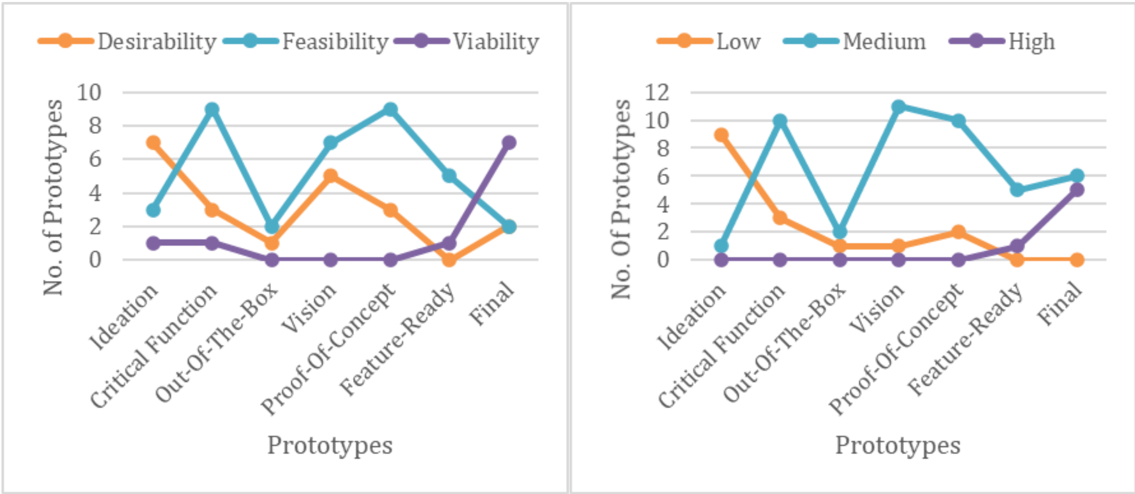


Figure 5. Prototyping Planners created for each activity mapped to the prototyping process. Team eight started with Critical-Function Prototype besides briefly considering other solutions, while skipping Ideation Prototype at the start. The findings lead to commit for the idea, shown by the fact that three Vison Prototypes were built to communicate their idea. With the feedback received, the team started testing the concept and created two Proof-of-Concept Prototype. Two Feature-Ready Prototypes were then built to estimate what is possible. Three additional prototyping activities were done as part of the Final Prototype.

Looking at the prototyping progress in terms of desirability, feasibility, and viability, it becomes apparent that the team tested nine times feasibility but only considered desirability once and viability twice. However, the team received good feedback from industry experts and has now filed a patent and received initial investment for the project.

3.3 Results

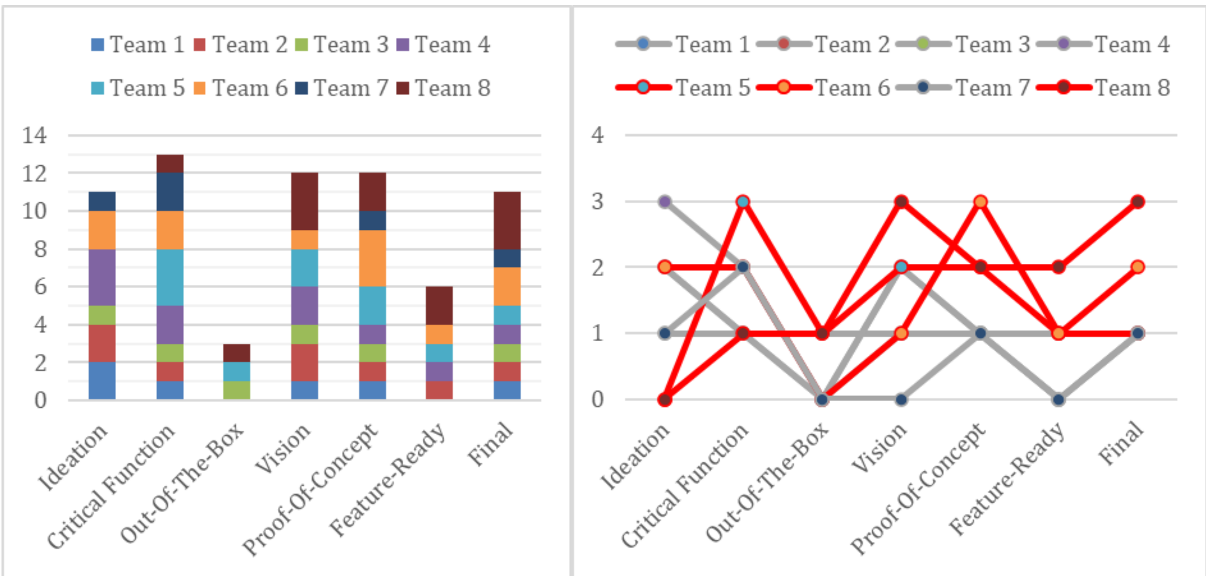
The data of eight teams was considered for evaluation and analyzed. The number of prototypes in respect of desirability, feasibility, and viability as well as low-, medium-, and high fidelity is illustrated in see Figure 6. In total, 21 desirability, 37 feasibility, and 10 viability prototypes were built and 16 low-, 45 middle-, and 6 high fidelity prototypes were built.



a) Desirability, Feasibility, and Viability *b) Low-, Medium, and High Fidelity*

Figure 6. (a) Desirability, Feasibility and Viability in relation to prototyping phases. The aspects of desirability and viability were first considered in the prototypes, followed by a shift to feasibility and desirability reaching its maximum and viability its minimum. Subsequent, prototypes in respect of feasibility declined, and desirability and viability rose (left). (b) Low-, Medium-, and High Fidelity in relation to prototyping phases. The teams started with low fidelity and ended with high fidelity prototypes. In between a lot of medium fidelity prototypes were built, while peaking at the Vision Prototype phase (right).

Considering the prototyping process of the individual teams as shown in Figure 7, it is evident that the teams have built more prototypes in the converging phase than in the diverging phase. Therefore, it can be assumed and emphasized that the focus of the methodology on prototyping has resulted in many prototyping activities.



a) Number of Milestone Prototypes *b) Number of Prototypes per Team*

Figure 7. (a) Number of Prototypes built by all teams in relation to Prototype Phases. 68 prototypes were built with an average of approximately 9 prototypes per team leading to almost one prototyping activity per

day. The teams built a total of eleven Ideation-, thirteen Critical-Function-, three Out-of-the-Box-, twelve Vision, twelve Proof-of-Concept-, six Feature-Ready-, and eleven Final Prototypes. (b) In the second sub-figure on the right, it can be observed that the winning teams (in red) prototyped more often during the entire developmental process than the other teams.

4 Discussion

4.1 Methodology

The RBPA methodology was successfully deployed and provided the teams with the necessary support to help each other in the Fuzzy Front-End (FFE) of New Product Development. The results show a need for improvement, especially for the team formation, where no support is provided in the current approach. It is merely helping the teams to find ideas and suggests using prototypes to visualize ideas. A prototype presenting the idea is mandatory to register the team. This approach might lead to individuals being left out in the team formation process. The advantage of self-selection is that teams are formed based on interpersonal relations or common interests. Admittedly, this has the risk that mostly homogeneous groups are formed leading to a loss of interdisciplinarity.

The three principles of Human-centred Design are integrated at the core of the RBPA methodology, leading to a split of responsibilities among team members. This promotes collaboration and reduces uncertainty in the Fuzzy Front-End. Several prototyping activities and its documentation are required in relation to the Human-centred Design principles to tackle this issue. It is likely that prototypes cover several principles in a test. However, this is not measurable, which leads to the question what principles are addressed by each prototype. This was an explorative study with the objective to test the methodology. With respect to the deployment of the methodology, we can speak of a success as most of the students used the approach accordingly and had a high amount of prototyping activities. It can also be observed that teams that embraced the methodology and tested individual concepts by prototyping faster and integrating better were more successful in deploying a minimum viable product. The impact of the methodology needs to be addressed at a later stage, yet additional challenges for improvement of the RBPA methodology remain, such as making the approach more coherent.

4.2 Contribution and Limitation

This explorative study builds on recent work in design research to help designers develop new products in the Fuzzy Front-End through prototyping by reducing uncertainty and risk. The focus is on a goal-oriented prototyping approach by providing structure and pushing designers in the development process. Efficiency is increased by a role allocation in the development process combined with a prototyping approach and to the three principles of Human-centred Design. This approach is designed for the application in student development projects at universities to prepare engineers for the new challenges of VUCA. A customized version of the PP (Hansen et al., 2020) for cross-domain makeathon formats was used supporting prototyping activities of teams. This experiment was a test on how to reduce dependency of coach guidance by giving structure through the approach in form of autonomy. The coach facilitation could not be removed completely. Additionally, the effectivity of the methodology has to be addressed as this time it was only used for deployment and merely data collection. Yet, it is a first successful step, which requires further research.

The roles provide a guideline, but are still ambiguous, as the exact function of each role were not clear. A possible improvement could be to modify and specify the individual roles.

Prototype milestones gave guidance, but the efficiency is questionable as the design space was not divided into a problem and solution space with the seven prototype phases used. This approach was only tested in an academic setting, casting doubt in the implementation in industry.

4.3 Conclusion and Outlook

The RBPA methodology was tested for the first time in the 10th iteration of TMS and evaluated. It shows that little support along the development process is superior to forcing teams with a strict approach. The current evaluation was mostly based on qualitative results from teams with project success and calls for more data driven ways to prove the success of this approach by including results from failure. For this, success for NPD needs to be defined with a corresponding metric to measure critical success factors. The RBPA methodology is designed for academia and raises the question if such approach is also transferable to industry contexts. An extension to the industry might be advisable. The value creation of RBPA is based on the three principles of HCD. These represent proven success factors for NPD. Research on further relevant principles should be conducted to consider the introduction of a fourth principle *sustainability* as a success factor, as some projects raised the question on its necessity. The objective should be to reduce uncertainty, to lower barriers and to support development.

5 References

Bennett, N., & Lemoine, J. (2014). What VUCA really means for you. *Harvard Business Review*, *92*(1/2).

Bhuiyan, N. (2011). A Framework for successful new product development. *Journal of Industrial Engineering and Management*, *4*(4). https://doi.org/10.3926/jiem.334

Böhmer, A. (2018). *When digital meets physical-Agile innovation of mechatronic systems.* Technische Universität München.

Carleton, T., & Leifer, L. (2009). Stanford’s ME310 course as an evolution of engineering design. In *Proceedings of the 19th CIRP design conference-Competitive design.* Symposium conducted at the meeting of Cranfield University Press.

Crawley, E. F., Malmqvist, J., Lucas, W. A., & Brodeur, D. R. (2011). The CDIO syllabus v2. 0. An updated statement of goals for engineering education. In *Proceedings of 7th international CDIO conference, Copenhagen, Denmark*.

Deming, W. E. (1989). Out of the Crisis. Quality, Productivity and Competitive Position. *Massachusetts Institute of Technology, Cambridge, MA*, *81*, 82.

Ernst, H. (2002). Success factors of new product development: a review of the empirical literature. *International Journal of Management Reviews*, *4*(1), 1–40.

Hallgrimsson, B. (2012). *Prototyping and modelmaking for product design*: Laurence King London.

Hansen, C. A., Jensen, L. S., Özkil, A. G., & Martins Pacheco, N. M. (2020). Fostering Prototyping Mindsets in Novice Designers with the Prototyping Planner. *DESIGN 2020 16th International Design Conference, Dubrovnik, Croatia (Accepted)*.

Hostettler, R., Böhmer, A., Lindemann, U., & Knoll, A. (2017). TAF agile framework reducing uncertainty within minimum time and resources. *International Conference on Engineering, Technology and Innovation (ICE/ITMC), 2017*, 767–775. https://doi.org/10.1109/ICE.2017.8279962

IDEO (2015). *The field guide to human-centered design*: Design Kit.

Koen, P. A., Ajamian, G. M., Boyce, S., Clamen, A., Fisher, E., Fountoulakis, S., . . . Seibert, R. (2002). Fuzzy front end: effective methods, tools, and techniques. *The PDMA Toolbook 1 for New Product Development*.

Koycheva, L., & Hostettler, R. (2019). *Forget your CV: Apply Like an Entrepreneur*. Retrieved from https://www.linkedin.com/pulse/forget-your-cv-apply-like-entrepreneur-lora-koycheva/

Otto, K., & Wood, K. (2001). *Product design: techniques in reverse engineering and new product development*: Pearson Education.

Ries, E. (2011). *The lean startup: How today's entrepreneurs use continuous innovation to create radically successful businesses*: Crown Business.

Takeuchi, H., & Nonaka, I. (1986). The new new product development game. *Harvard Business Review*, *64*(1), 137–146.

Trott, P. (2016). *Innovation Management and New Product Development*. *Always learning*: Pearson. Retrieved from https://books.google.de/books?id=RoIHkAEACAAJ

Uebernickel, F., Brenner, W., Pukall, B., Naef, T., & Schindlholzer, B. (2015). *Design Thinking: Das Handbuch*: Frankfurter Allgemeine Buch.

Ulrich, K., & Eppinger, S. (2011). *Product Design and Development*: McGraw-Hill Education. Retrieved from https://books.google.de/books?id=ftPBYgEACAAJ

Vetterli, C., Brenner, W., Uebernickel, F., & Berger, K. (2012). Die Innovationsmethode design thinking.

World Economic Forum (2016). The future of jobs: Employment, skills and workforce strategy for the fourth industrial revolution. In *Global Challenge Insight Report, World Economic Forum, Geneva*.

Zirger, B. J., & Maidique, M. A. (1990). A Model of New Product Development: An Empirical Test. *Management Science*, *36*(7), 867–883. https://doi.org/10.1287/mnsc.36.7.867