



*What would
change if I used
a different
material?
Exploring
Visualisations of
Dynamic
Parameter-
Based Adaptions
in Collaborative
Process
Documentation
for Makers*

Diese Arbeit wurde vorgelegt am
Lehrstuhl für Informatik 10.

Bachelor's Thesis
submitted to the
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Registration date: 05.07.2021
Submission date: 28.09.2021

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Abstract

The maker culture is built around creativity, collaboration and mutual support. Do-it-yourself platforms do not always reflect these qualities of the maker scene though. In this thesis, we began our research by generating ideas regarding how to improve makers' experience on DIY platforms. Out of the ideas we generated, we chose to pursue the idea of *spin-offs*.

When trying to improve on a pre-existing project or rebuild it differently, makers mostly have to publish a new project. This results in having lots of projects on DIY platforms that share many similarities, yet are not linked together. Not only does this clutter DIY platforms, but also hinders successive development of new ideas, and could prove confusing for newcomers in the maker community. By having to create a new project for each variation, DIY platforms make it effectively more difficult for makers to collaborate on improving projects ideas or in sharing their vision of how the project could be done differently.

To improve this situation, we investigate the idea of spin-offs. Spin-offs make it possible for makers to view and create new variations of pre-existing projects, the get embedded in the original project. After developing multiple prototypes that showcase the spin-off feature, we investigate in a user study how the participants perceive the prototypes, and what their stance regarding spin-offs as a concept generally is.

In the study, we collected both quantitative and qualitative data. Based on the results of the study, we draw design implications regarding how DIY platforms could implement the spin-off feature. The results indicated, that makers favoured binding spin-offs to project steps. When viewing spin-offs, makers preferred a sidebar menu.

Überblick

Die Maker-Kultur ist auf Kreativität, Zusammenarbeit und gegenseitige Unterstützung ausgelegt. Do-it-yourself-Plattformen spiegeln diese Qualitäten der Maker-Szene jedoch nicht immer wider. Wir haben in dieser Arbeit unsere Forschung damit begonnen, Ideen zu entwickeln, wie die Erfahrung der Maker auf DIY-Plattformen bereichert werden kann. Von den generierten Ideen untersuchen wir die Idee der *Spin-offs*.

Wenn Maker versuchen, ein bereits bestehendes Projekt zu verbessern oder anders zu gestalten, müssen sie meist dafür ein neues Projekt veröffentlichen. Das führt dazu, dass viele Projekte auf DIY-Plattformen zu finden sind, die viele Gemeinsamkeiten unter sich haben, jedoch nicht verlinkt sind. Dies führt nicht nur zur Unübersichtlichkeit auf den DIY-Plattformen, sondern verhindert auch die sukzessive Entwicklung neuer Ideen und könnte sich für neue Mitglieder der Maker-Gesellschaft als verwirrend erweisen. Da für jede Variante ein neues Projekt erstellt werden muss, erschweren DIY-Plattformen die Zusammenarbeit der Maker. Dadurch ergibt sich ein höherer Aufwand für die Maker bei der Verbesserung von Projektideen bzw. beim Austausch ihrerer Vorstellungen darüber, wie ein Project anders gebaut werden könnte.

Um diese Situation zu verbessern, untersuchen wir die Idee der Spin-offs. Spin-offs ermöglichen es den Makern, neue Varianten bereits bestehender Projekte anzuzeigen bzw. zu erstellen, die in das ursprüngliche Projekt eingebettet werden. Nach der Entwicklung mehrerer Prototypen, die die Funktionalität der Spin-offs präsentieren, untersuchen wir in einer Nutzerstudie, wie die Teilnehmer die Prototypen wahrnehmen und wie sie generell zu den Spin-Offs als Konzept stehen.

Wir haben in der Studie sowohl quantitative als auch qualitative Daten erhoben. Aus den Ergebnissen der Studie leiten wir Design-Implikationen ab, wie DIY-Plattformen Spin-offs umsetzen könnten. Die Ergebnisse zeigen, dass Maker Spin-offs vorziehen, die an die Projektschritte gebundenen sind. Beim Anzeigen der Spin-offs bevorzugten die Maker eine Seitenleiste.

Acknowledgements

I would like to thank Prof. Dr. Jan Borchers as well as Prof. Dr. Ulrik Schroeder for examining my thesis.

Furthermore, I would like to thank my thesis supervisors, Marcel Lahaye and René Schäfer, for their feedback, their patience and their support.

Thank you to all the participants that took part in the study and shared their feedback with me.

Conventions

Throughout this thesis, we use the following conventions:

Text conventions

The whole thesis is written in British English. We refer to the first as well as unidentified third person in plural form.

Access links to project materials are set off in a coloured box.

Project: [myProject](#)^a

^ahttp://hci.rwth-aachen.de/public/project_number.file

Chapter 1

Introduction

1.1 Personal Fabrication

Personal fabrication, especially by having an at-home factory to realise own projects, has been an active HCI research topic for multiple decades. This active research has led to the development of a democratisation trend of manufacturing technologies, such that access to fabrication tools has become easier than ever. In his book FAB, Gershenfeld [2005] described his imagination of a machine called *personal fabricator* that had the potential to revolutionise the world just as personal computers once did. In his vision, personal fabricators would combine the computational power of PCs with industrial manufacturing tools, thus giving its user the potential to make "*almost anything*".

The vision of accessible personal fabricators was discussed in Gershenfeld's FAB book in 2005.

Gershenfeld's vision was not as far-fetched as it may first appear. His book gave birth to the now commonly known *fab labs* (*fabrication laboratories*). As discussed in Mota [2011], these labs are typically equipped with several CNC machines such as millers, 3D printers and laser cutters. By using the provided machines in these fab labs, hobby makers can gain access to machines that were deemed exclusive to mass production. This easy-to-gain access to CNC machines has helped the *DIY* (*Do-It-Yourself*) movement gather more momentum.

Fab labs provide fabrication tools for hobby makers.

The DIY movement aims to develop handcrafting skills.

As described in Kuznetsov and Paulos [2010], DIY is a movement that aims to revive the practice of self-involvement and the use of craft skills. At the beginning of the industrial revolution in the second half of the 18th century, the need of ordinary citizens to have a basic general knowledge of handcrafting practises shrunk down, while the need of individuals to specialise in a certain domain of knowledge kept growing. The DIY movement thus aims to motivate people to develop their crafting skills and seek knowledge to complete tasks, that would have otherwise required hiring professional help.

1.2 Documentation Patterns

The DIY movement lives off knowledge sharing.

As the philosophers Levy and Bononno [1997] once put it in their book when talking about the period between 1751 and 1772 at the beginning of the industrial revolution, they described that period as *"the end of an era in which a single human being was able to comprehend the totality of knowledge"*. For that reason, and as the DIY movement attracted more supporters and gained momentum, the need to document and publish completed projects for knowledge transfer and as a future reference grew bigger. In a survey of 2600 individuals, Kuznetsov and Paulos [2010] collected data regarding how often makers choose to publish their projects. As figure 1.1 shows, only about 8% of the surveyed individuals said they published all of their projects. About 10% said they had never published any of their projects before.

Makers do not document all of their work.

One of the most common reasons why surveyed makers said they had not documented their projects, is because they had believed their project ideas were not necessarily new or were not creative enough. Yet successive small improvements of preexisting project ideas could lead to the improvement of the project overall and how it can be utilised. In an ideal maker documentation platform based on knowledge exchange and creativity, makers should not have to invent something from scratch for it to be worthy of sharing with others.

We generate some ideas in this thesis regarding how mak-

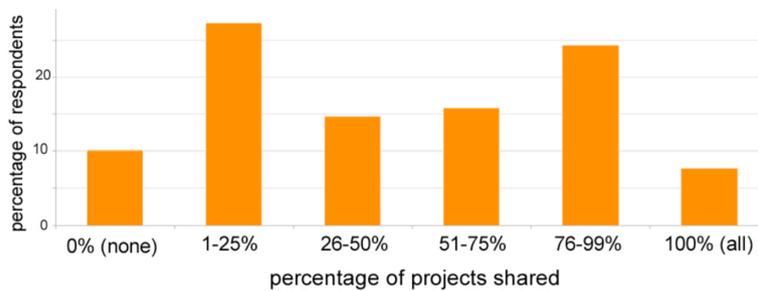


Figure 1.1: DIY projects shared with DIY communities. Only about 8% of the respondents said they had published all of their projects. Image taken from Kuznetsov and Paulos [2010].

ers' experience on DIY platforms can be improved. We then focus on the above-mentioned situation in DIY project documentation. As a potential solution, we explore the idea of remixing projects in what we call *spin-offs*. Spin-offs give makers the ability to publish a modified version of a pre-existing project by editing one or more steps. The newly published spin-off would be embedded into the original project. This could allow for a higher degree of member collaboration. Not only would project creators potentially benefit from having the ability to create spin-offs, but also project viewers could benefit from the inspiration of having different project variations grouped in one place.

Spin-offs could help improve makers' experience on DIY platforms.

1.3 Outline of the Thesis

We begin in chapter one by introducing the concept of personal fabrication and how it defines the DIY movement. We also describe the documentation patterns in the maker community and how the idea of spin-offs could potentially lead to easier project collaboration. In chapter two, we discuss related work to the topic of this thesis. As for the third chapter, we move on to discuss different ideas that could potentially improve makers' experience on DIY platforms.

The fourth chapter of this thesis takes a closer look at the idea of spin-offs and outlines several proposed visualisations. Through a moderated user study, we investigate in

the fifth chapter how makers perceive the spin-off idea and how they would potentially interact with the proposed prototype designs. In the sixth chapter, we discuss the results of the user study and evaluate the prototypes.

In the seventh chapter, we introduce an implemented prototype that showcases the spin-offs feature according to the drawn conclusions from the user study. As for the eighth and final chapter, we sum up the contents of this thesis and discuss further relevant extensions for future work.

Chapter 2

Related work

In this chapter, we begin by discussing the maker culture and what motivates makers to make. We discuss the results of several research papers that tried to analyse behavioural patterns within the maker community. Furthermore, we survey papers that investigated project documentation philosophies from multiple vantage points and how they unfolded within the maker community. We also present the results of papers that investigated what constitutes good documentation and what motivates makers to document.

At last, we introduce some of the popular maker documentation platforms and talk about what sets them apart. We also discuss the patterns of remixing in some of the maker platforms and how makers perceive and utilise this feature of being able to contribute to pre-existing projects.

We survey research papers regarding DIY platforms and the maker culture.

2.1 The Maker Communities

The maker community is used as a term to collectively refer to people, mostly non-professionals with a non-commercial nature, who take it upon themselves to build or modify existing technologies so that they better fit their needs. As discussed by Kuznetsov and Paulos [2010], the relation-

There is a mutually beneficial relationship between makers and technological advancements.

ship between the maker communities and the continuous technological advancement has been reciprocally beneficial. New technologies make it easier for makers to fabricate at a small scale and collaboratively work on projects, while makers being able to easily implement and test their endeavours gives birth to new ideas that help push technological progress.

The maker community has low entry barriers.

To better understand the dynamics of the maker community, Kuznetsov and Paulos [2010]'s paper investigates the underlying characteristics of the maker culture. A major factor that distinguishes the maker community is the low entry barriers to become a maker. Prospective makers do not have to bring any specific domain knowledge. The maker community welcomes people of different technical and artistic backgrounds. This heterogeneity of the maker community catalyses the exchange of ideas from different perspectives. An anchor of the maker community is as well the constant openness to learning about new technologies and materials. The intercommunication between makers helps them acquire new skills and learn about new concepts that they utilise in their projects. A further factor that Kuznetsov and Paulos [2010] discuss is open sharing. Knowledge sharing and openly talking about project ideas helps junior makers learn common practices in the maker community and gives them a head start regarding the used technologies. Sharing also helps makers connect with like-minded members of the community. Building a personal connection adds a social dimension to the maker scene which leads to strengthening the bonds within the community.

There is a social aspect to the maker community.

A closer look at the social aspect in the maker communities in figure 2.1 shows that in a conducted survey with 2600 participants, about 90% of the respondents said that they contributed to the maker community by asking questions about others' projects or making comments. More than 80% of the surveyed participants said they contributed to the maker community by posting pictures of their own projects or asking questions to get help with their own projects. Looking at the frequency of these contributions, about 19% said they would daily respond to questions or comments and about 17% said they daily posted questions or com-

ments about others' projects. This shows how the social aspect of open-sharing and mutual help plays a vital role in the maker community.

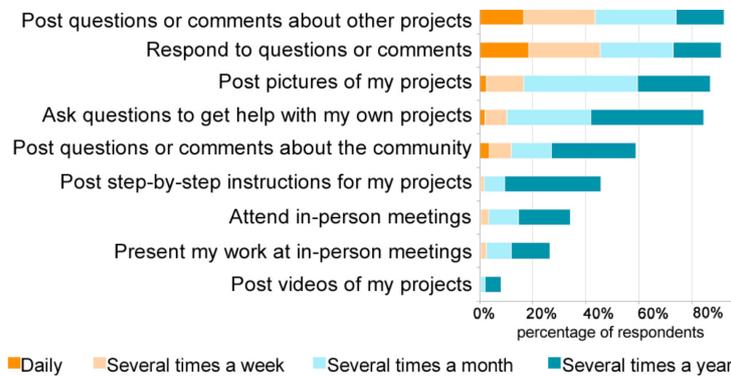


Figure 2.1: Contribution forms to maker communities. Image taken from Kuznetsov and Paulos [2010].

A further look at the motivations for contributing to the maker community in figure 2.2 reveals that slightly over 80% of the surveyed participants strongly agree with the statement that they use maker platforms as a means to get inspiration and new ideas for future projects. Over 65% of the participant strongly agreed that maker communities helped them learn new concepts. A total of almost 80% strongly agreed or agreed with the statement that maker communities helped them meet new people, with whom they shared interests. The results of this survey give us insight into how makers perceive their community and would help in making the design choices for potential solutions that meet the makers' expectations.

Makers use DIY platforms to learn about new concepts and to connect with others.

Being able to make empowers consumers. Tanenbaum et al. [2013]'s paper describes the context of technological democratisation from the perspective of makers. The democratisation of technology means making it accessible to non-professionals at a low cost. The maker community, at its core, lives off the fact the technologies are constantly getting obsolete, thus cheaper and easier to experiment with. This decreases the financial burdens to become a maker. Technological democratisation also means that devices, that once used to be exclusively available to only large organisations, can now be made accessible to the general public. Examples include 3D printers and laser cutters.

Technological democratisation has an influence over the maker community.

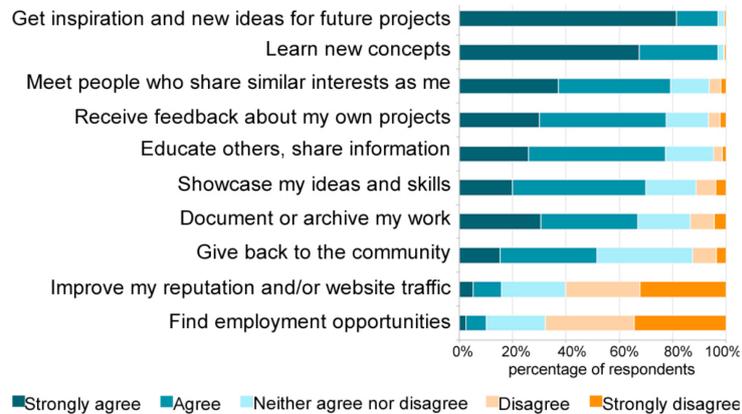


Figure 2.2: Motivations for contributing to maker communities. Image taken from Kuznetsov and Paulos [2010].

Makers take pleasure in using new technologies.

Tanenbaum et al. [2013]’s paper further describes how the concept of technological hedonism played its role in the maker community. Technologies can be categorised as hedonic, once they are mainly utilised for the pleasure of using them, over the significance of the resulting product. Since makers are mostly amateurs who practise making for non-commercial reasons, but mainly as a hobby and with the purpose of self-fulfilment, technologies used by makers can thus be described as hedonic.

Designing technologies for the maker community.

With the concept of hedonism in mind, Tanenbaum et al. [2013] draw design implications for technologies and services that are to be used by makers. First of all, these services should be built to enable creativity. A boost for creativity is allowing open collaborations on projects as a mechanism for the dissemination of knowledge. A further implication is to design services for utility, pleasure and expressiveness. Pleasure and expressiveness go hand-in-hand with the concept of hedonic technologies we described. Since maker technologies are used by many people, they have to be easily and efficiently utilisable.

2.2 Project Documentation

As discussed in the previous section, one of the cornerstones of the maker community is knowledge sharing and mutual support. For this to happen, makers need to document their work and be willing to share it with the rest of the community.

2.2.1 Documentation Guidelines

In their paper, Wakkary et al. [2015] discuss the factors that make up a good tutorial. According to their findings, a tutorial should clearly include information regarding the prerequisites and the needed skills for completion. This helps the potential makers set the right expectation level for the effort needed to complete the project. To ensure the makers' ability to follow the project, the tutorial steps need to be clearly sequenced and include all the information required to complete the task. This usually entails having auxiliary multimedia material that helps makers better understand each step. Tutorial authors should also take the placement of the multimedia material into consideration, such that images describing a specific instruction, for example, should be placed near to the textual description of that instruction.

Practices in project documentation for makers.

Information accuracy is a deciding factor when it comes to tutorial quality. Misleading instructions or incomplete information lead to user confusion and dissatisfaction. This implies that tutorials, for example, should include the necessary information regarding needed tools and components. To accurately deliver the execution instructions, the project has to be broken into a reasonable number of steps, such that each step mainly handles one instruction.

Information accuracy plays an important role in the documentation process.

2.2.2 Documentation Philosophies

Tseng and Resnick [2014]'s paper examined documentation approaches makers follow. The paper distinguishes be-

tween two approaches: Product-based and process-based documentation.

Product-Based Documentation

This approach follows a recipe-like format for delivering the documentation. Authors using the product-based approach would try to list the project instructions in a successive manner as a list of steps that replicating makers would need to follow to complete the project. Just like a recipe, this approach would first entail mentioning the ingredients - or the required materials and tools in a maker project's case, then proceeding with the execution steps. Figure 2.3 depicts how makers normally document their project when using this approach. As discussed in Tseng [2016], as well as Tseng and Resnick [2014], authors utilising this approach would usually start writing the tutorial after finishing the project. This could lead to the authors forgetting the right order of the steps. In some cases, authors would completely forget to mention some steps. To remedy this, some authors would go as far as replicating the project after making it for the first time to make sure their created tutorial includes all the needed instructions to recreate the project. In the case of a large scale project though, replicating the project could imply an excessive overhead that discourages makers from documenting their work.

Makers usually document the project after finishing it in product-based documentation.

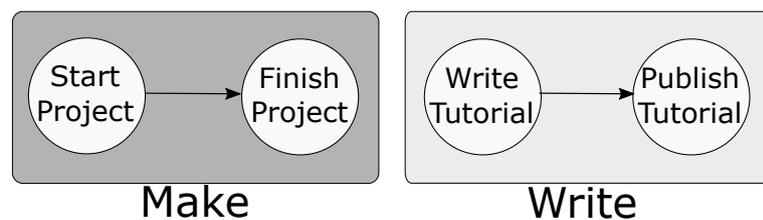


Figure 2.3: Product-Based documentation. Image based on Tseng [2016].

Product-based documentation only delivers steps to replicate the project.

One further aspect that product-based documentation lacks, is that it only delivers the steps needed to replicate the project. No information regarding the making process, such as the failed attempts, the inspiration sources, or the potential alternative materials is mentioned. This missing

information could lead potential replicating makers into repeating the same mistakes the original author fell for.

Process-Based Documentation

The second approach is to document the making process, instead of merely documenting the final product. In this approach, makers are simultaneously documenting their projects while they are working on building them. Figure 2.4 shows how documentation takes place in the process-based approach. Makers utilising this approach could easily integrate more information regarding the challenges they faced, their thought process as well as potential alternatives to certain steps. One advantage of this approach is that the multimedia material can be directly collected while working on the project without having to replicate the project later. As figure 2.2 shows, makers mostly look at documentation platforms as a source of inspiration and ideas for future projects. Using the process-based documentation approach, and thus providing background information regarding the project instructions, could better help makers looking for inspiration.

In process-based documentation, makers document their projects while building them.

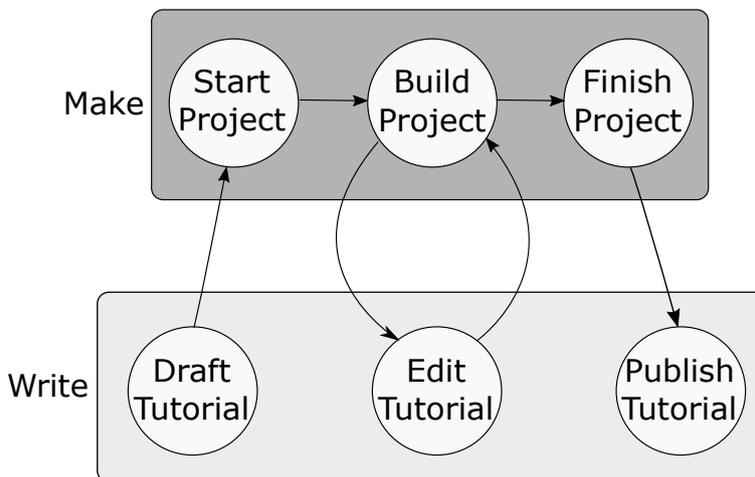


Figure 2.4: Process-Based documentation. Image based on Tseng [2016].

Following, we present some solutions based on research papers that tried to aid the process-based documentation

process. We used the solutions and the results based on these research papers as an inspiration during the idea generation phase in chapter three.

Log files could be used to automatically generate heatmaps in digital fabrication.

Using log files, Tseng and Tsai [2015]’s paper presented a simplified approach for automating process-based documentation in the case of digital fabrication. Digital fabrication entails the authors designing a model using computer software. The log files generated by the software used to design the model can be used, for example, to automatically generate a heatmap that graphically shows the successive changes that were made to the model. This heatmap can help makers attempting to recreate the model better understand how it was built.

Makers could use a mobile app to take notes while building their projects.

A further implementation of the process-based documentation philosophy was discussed in Sanchez Milara et al. [2019]’s paper. In their implementation, they tried to derive functional requirements based on the users’ needs in process-based documentation. For one, their implemented platform attempted to fulfil the users’ need for having a system that helps them remember the project steps as well as their right order. To achieve this, they proposed a solution of using a mobile application that makers could use to take audio and written notes as well as record multimedia content that could help them remember the details regarding the project steps.

2.3 **Maker Documentation Platforms**

In this section, we present the results of research papers that discuss guidelines for designing maker documentation platforms. We then present results from papers that examined the patterns of hybrid design and tutorial remixing in the maker community. The relevancy of this section to our thesis is based on the fact that we attempt to explore potential extensions for maker platforms that allow for a better experience for makers. We, therefore, examine relevant research to the topic of maker platform creation and design remixing behaviour.

2.3.1 Platform Creation Manifesto

The paper De Roeck et al. [2012] presents a multiple-factor manifesto for designing maker platforms. Among others, their manifesto includes instructions on how to structure the content on the designed platform. According to their manifesto, the platform should be able to support collaboration between users to encourage knowledge exchange and mutual support. Furthermore, the platform should be able to support publishing evolving projects. Evolving projects are ones that are still in the making process. As discussed in the previous section, being able to publish evolving projects falls under the category of process-based documentation. Moreover, the platform should be designed in a way that benefits all stakeholders. For example, the content on the platform should be designed in a way such that it supports users of diverse technical backgrounds with different skill sets.

Maker platforms should be designed to support collaboration.

A further aspect to consider when designing maker platforms is how makers are going to search through that platform to find projects. The paper Torrey et al. [2009] presents a discussion of how makers' search experience can be improved. They suggest adding the option to filter projects by skill level as well as required time investment. They also make the case for novice makers, that they often lack the required technical knowledge to come up with the right keyword when they are searching for projects. This paper makes a suggestion to use social search strategies to create a quasi equivalence class of potential keywords that could lead to similar search results. This could result in building a more inclusive platform that better supports users searching for a project using a relevant, yet inaccurate keyword.

Maker platforms should support novice makers.

2.3.2 Design Remixing in the Maker Community

In their paper, Oehlberg et al. [2015] analyse how users of the maker platform *Thingiverse*¹ use the platform's feature *Customizer* to modify pre-existing projects. Thingiverse is

¹<https://www.thingiverse.com/> (Accessed: 12.09.2021)

Users can remix designs on Thingiverse.

an online community for 3D model designs. Models—so-called *Things*—shared on Thingiverse are used in digital fabrication, for example, these *Things* can be printed using 3D printers. Users who share their 3D models on Thingiverse can publish a parameterised version that allows other users of the platform to alter the model by modifying those parameters using the Customizer feature.

Activity on Thingiverse increased after introducing the remixing feature.

As figure 2.5 shows, the Customizer feature was released on Thingiverse early 2013. Within a year, the total number of projects on Thingiverse nearly tripled. By analysing the authorship activity of the users on Thingiverse, the paper shows that after the introduction of the Customizer feature, the number of the authors and, consequently, the number of published *Things* increased. This indicated how potentially giving makers the option to tweak or adjust pre-existing projects could lead to a more active maker community.

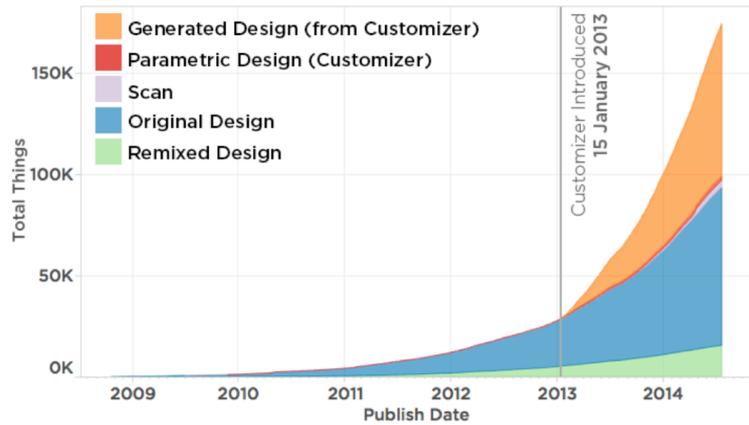


Figure 2.5: *Things* published on Thingiverse. Image taken from Oehlberg et al. [2015].

Chapter 3

Idea Generation

With the goal of enhancing the makers' experience on documentation platforms, we present in this chapter selected ideas we generated. In the following sections, we will be briefly discussing these ideas and how we think they could contribute to a better makers' experience.

We generated ideas on how to improve makers' experience on documentation platforms.

3.1 Dynamic Website Content

The basic premise of this section is that makers would be able to better engage with tutorials, whose contents are more suitable for their profile. We explore in this section multiple ideas on how tutorials' contents could be tailored to fit a heterogeneous maker base.

3.1.1 Profile-based Skills and Experience

By giving makers the ability to set their level of experience with specific materials or crafting skills such as soldering or 3D printing, tutorial content could be automatically tailored to fit the respective maker's profile. According to a maker's profile, tutorial content could automatically expand on specific steps by showing further details including

Tutorials can dynamically change according to the user.

multimedia content. Conversely, some explanations in specific steps could be reduced if a maker's profile warrants previous experience regarding these explanations. Dynamically changing tutorials contents to fit the makers' knowledge level could potentially motivate makers' to engage more with tutorials that they would normally deem too difficult for their skill level. This could encourage makers to learn about new technologies and acquire additional skills.

An expansion of this idea is to continuously readjust the maker's skill level based on the projects they completed. This could help maintain adequate tutorial content that fits the maker's skill set and experience level.

3.1.2 Tutorial-based Skills and Experience

Makers are in control of the level of details in tutorials.

Analogous to the last approach, we consider in this idea how to tailor tutorials' contents to fit makers' profiles. Instead of setting the experience level regarding certain materials or crafting skills on the profile page, makers would be presented in this approach with a list of needed skills for a specific project on the project's tutorial page. Makers could adjust the level of detail for each parameter according to their needs. The tutorials' content would be adjusted accordingly.

This list of parameters representing the needed skills would be set by the tutorial author when he or she first published the project. The advantage of this approach, in comparison to the last one, is that makers would not need to set a level of experience for an extensive list of parameters on their profile page. Instead, they would be directly able to adjust the level of detail they want to see for only the parameters that appear on the project they are interested in completing.

Assessing makers' experience by asking them questions.

A different approach to capture a maker's experience level is to present a list of assessment questions at the beginning of a project or while reading through it. These could be basic questions regarding the maker's experience with the specific crafts or skills that will be utilised in the project they are interested in. By answering these questions, the

maker's experience level could be evaluated and the tutorial content automatically adjusted as previously described.

3.1.3 Location-based Supplementary Content

Based on a maker's location, we could provide auxiliary information on the tutorial page that could help the maker better complete the project. For example, in a project discussing a 3D model that can be printed, we could automatically present—based on the maker's location—information regarding the nearest Fab lab where the 3D model could potentially be printed.

Using geographical information to improve makers' experience.

In case there is a Fab lab nearby that is offering introductory courses into 3D printing, we could present such information as well. This could be considered as a potential expansion of the previous two approaches.

3.2 Encouraging Community Activity

In this section, we explore approaches that could facilitate community formation and encourage makers to actively contribute. As discussed in Morreale et al. [2017], building a maker community based on mutual support and knowledge exchange is key for creating a platform where makers with different skills sets feel included, and thus can better achieve their learning goals.

Building maker communities on DIY platforms.

3.2.1 Adding Tips and Asking Questions

Without having to resort to a standalone forum, we propose in this approach that giving makers the option to add tips or ask questions regarding specific project steps in the project page directly would allow for a more interactive community.

Embedding questions and tips into tutorial pages.

For other makers viewing a project, they would be able to

see previously added tips or questions regarding a specific step directly on the project page. We believe that integrating tips and questions into their corresponding steps would lead to a better maker experience. This could be especially beneficial to inexperienced makers.

Integrating failed attempts into project steps.

When it comes to process-based documentation as discussed in chapter two, this approach of integrating tips and questions into related steps could be expanded to also include failed attempts at completing a specific project step. This could help makers in the process of completing a project avoid what led to these failed attempts.

3.2.2 Rewarding Interactivity

Makers could earn points for being active community members.

A way to encourage community interactivity is to reward makers for being active. Makers can score achievements or be rewarded points for every project they share or question they answer. These points can, for example, lead to a higher placement on a leaderboard. Adding this gamification aspect into documentation platforms has the potential of encouraging makers to be more active.

Hofferbert et al. [2015] published a paper discussing the gamification architecture used on Thingiverse. We could potentially analyse Thingiverse's architecture to investigate how it affected the community interactivity as a preliminary step to develop further ideas that reward user interactivity.

Publishing voice recordings in documentations.

A research paper published by Sukale and Pfaff [2014] proposed an approach of building a reward-based documentation platform for developers, where developers, in addition to written documentation, can publish voice recordings of their code explanations. Further investigation is needed to see whether such an approach would be appropriate for maker platforms as well.

3.2.3 Connecting Users

To encourage user activity, giving makers the opportunity to find others who share the same interests or are currently working on similar projects could prove helpful. By creating workgroups, makers working on different projects that share similar materials or require comparable crafting skills could join a workgroup where they could mutually support each other by sharing ideas or asking and answering questions.

Connecting makers working on similar projects.

A workgroup can be structured to only allow a limited number of makers to join. Getting in touch with other makers in a smaller workgroup in comparison to an open forum could potentially allow for a more personal mutual support experience.

Workgroups allow for a more personal contact.

3.3 Supporting Documentation Collaboration

As discussed in chapter two, documentation is crucial for the maker community to evolve. Accordingly, we take interest in this section in ideas that support collaborative work on creating and modifying project documentations.

3.3.1 Spin-offs

Using online project tutorials, makers follow the documented project steps to recreate the project. But what if a maker wants to publish a modified version of the same project that shares most of the steps with the original project, yet utilises a different material? One approach would be for the maker to publish a new tutorial that utilises that other material. Another approach would be to post a comment on the original project that discusses how to rebuild the project using the other material. In case the maker decides on the former approach, posting a new separate project for every alteration of the original project

Creating variations of pre-existing projects.

Drawbacks of publishing variations as new projects.

would clutter the documentation platform and could potentially confuse future makers, who want to replicate the project. As the new project is not linked to the original project, much of the shared knowledge through makers' shared comments or suggestions on the original project is lost in the newly created one.

Drawbacks of publishing variations in the comments.

In case the maker decides to go for the latter approach by posting a comment on the original project, this comment risks being easily overseen by other makers who might be wondering about using that same material. This comment would not be integrated into the project steps either, but would require future makers to actively seek it in the comments section.

Spin-offs are embedded variations of project instructions.

To address these issues, we propose the concept of *spin-offs*. Using spin-offs, makers would be able to create variations of project instructions that are directly integrated into the project page. Accordingly, makers who want to publish a modified version of a pre-existing project would not need to create a completely new project or post their idea in a comment. Instead, they would be able to create a spin-off of the instructions that they want to change, thus making it easier to document and contribute to the maker society.

The instructions, that are modified by a spin-off, influence one or more parameters of the project. For example, a spin-off that shows how to rebuild a pre-existing project using a different material would modify the parameter *project material*. A *parameterised spin-off* is thus a spin-off, for which the parameters have been determined, which that spin-off modifies.

There could be multiple parameterised spin-offs that address the same parameter. To better organise spin-offs, we propose an approach of grouping parameterised spin-offs under the name of their common parameter. For example, all spin-offs addressing the parameter *project material* would be grouped together. The name of that group would be *project material*.

There are possible benefits of spin-offs.

Potential benefits extend beyond just facilitating project documentation. For the rest of the makers that are view-

ing a project, they would be able to find multiple variations of project instructions linked together on the same project page, thus giving them more alternatives and potentially encouraging their learning process.

3.3.2 Tutorial Integration and Reusability

In this idea, we propose an approach that allows makers in the process of creating a project to integrate pre-existing tutorials into their projects.

Assuming there is a maker documentation platform hosting a tutorial discussing how to build car wheels. A maker that is creating a new tutorial on how to build a remote-controlled car could directly integrate the tutorial discussing how to build wheels into his car tutorial. This feature could potentially make it easier for makers to reuse pre-existing tutorials in their project documentation. Reusability of pre-existing projects could also help reduce redundancy in maker documentation platforms.

Pre-existing projects can be reused in new ones.

Chapter 4

Prototypes

For the purpose of this thesis, we decided to further investigate the idea of *parameterised spin-offs* as presented in section 3.3.1. We believe the potential benefits of the spin-offs feature would improve the makers' documentation experience. For the sake of conciseness, we will be calling from now on *parameterised spin-offs* just *spin-offs*.

We investigate the idea of spin-offs.

To investigate these benefits and how spin-offs could potentially be implemented, we built a series of prototypes. These prototypes utilise various approaches regarding how the spin-offs feature could be integrated into maker platforms. In the following sections, we will be discussing these approaches regarding how makers can create and view spin-offs. All prototypes were created using Adobe XD¹.

The prototypes can be found on the following GitLab repository:

Adobe XD Prototypes^a

^a<https://git.rwth-aachen.de/MichaelA/magora/-/tree/main/AdobeXD>

¹<https://www.adobe.com/de/products/xd.html> (Accessed: 02.09.2021)

4.1 Showing Spin-off

Different aspects of the prototypes.

In the prototypes we created, we experiment with different constellations of the following aspects regarding how to show spin-offs. These aspects are:

- Possible placements of the button to show spin-offs on the tutorial page.
- Showing spin-offs through a wizard or through a menu.
- Possible placements of the spin-off menu that appears once the appropriate button has been clicked to show the spin-offs.

The prototypes we created are divided into four groups.

We created seven prototypes. According to the used constellation of the previously mentioned aspects, the prototypes can be categorised into four groups. Each of these groups consists of two prototypes, with the exception of one group having a single prototype. We will be describing each of these groups in the following subsections.

Group One

For this group, we test in two prototypes two different placements of the *Show Spin-offs* button. By clicking that button, spin-offs appear as an overlay menu showing the different parameters that can be manipulated.

Spin-offs at the focus of the screen.

By hovering over any of the parameters in the overlay menu, the text sections are highlighted that would change by altering that parameter. Figures 4.1 and 4.2 show how the overlay menu looks like. Our goal was to integrate spin-offs into the tutorials. By using this menu design, we wanted to see how users perceived a design that placed the spin-off menu over the tutorial text at the focus of the screen.

Version One

In this prototype version, the button to show spin-offs is located next to each step where a spin-off is relevant. By clicking on the *Show Spin-offs* button, the above-described overlay menu appears. The displayed parameters in that menu are limited to the relevant parameters of the specific step where the *Show Spin-offs* button was clicked.

Step-based spin-offs with an overlay menu.

Figure 4.1 shows the location of the *Show Spin-offs* button. In that figure, the button next to the second step was clicked.

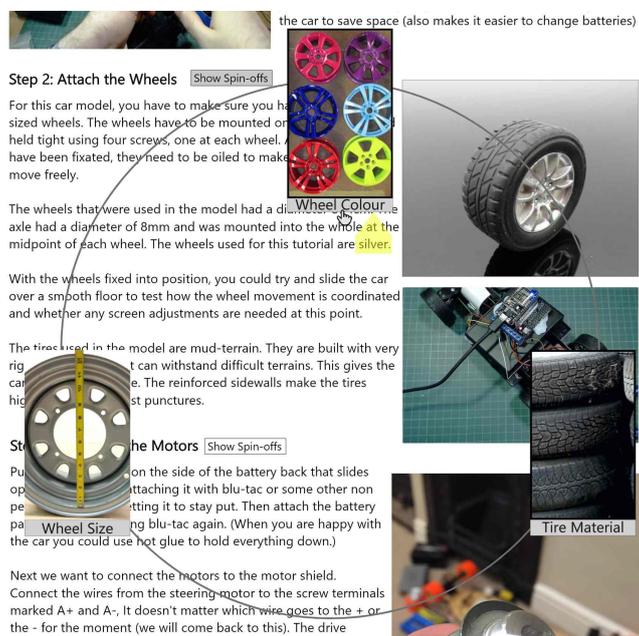


Figure 4.1: Version one for showing spin-offs. The button to show spin-offs is directly placed next to the step. Spin-offs appear as an overlay. Images from left to right, top to bottom(L.R.T.B): [11,21,3,12,8,10,13], text based on [27].

Version Two

For this version, we tested a different placement of the button responsible for showing spin-offs. Instead of placing the button next to each step, we placed the button at the top

Project-based spin-offs with an overlay menu.

of the tutorial page. This button is responsible for showing all the spin-offs of the given tutorial. Consequently, the menu that appears after clicking this button contains all possible parameters for the whole tutorial and is not limited to a specific step.

Analogous to version one, spin-offs are presented as an overlay menu. As shown in figure 4.2, hovering over a parameter in this overlay menu highlights the passages of the text that would be modified by altering a specific parameter.

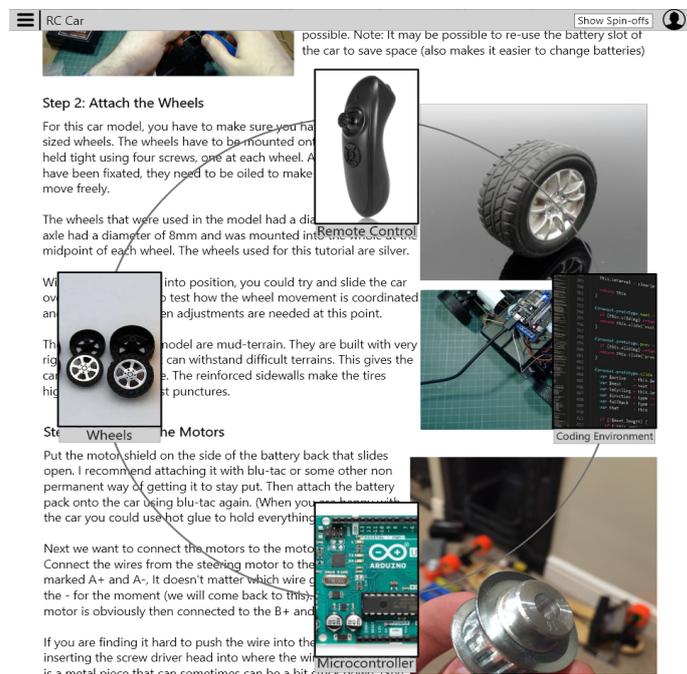


Figure 4.2: Version two for showing spin-offs. The button to show spin-offs is placed at the top of the tutorial page. Spin-offs appear as an overlay. Images from L.R.T.B: [11,26,3,4,7,12,19,13], text based on [27].

Group Two

Showing spin-offs in a sidebar menu.

In the following prototypes, we test two different placements of the *Show Spin-offs* button. By clicking on the button, a sidebar appears that contains the relevant spin-offs, grouped according to the influenced parameters. Figures

4.3 and 4.4 show how the sidebar looks like. We wanted to experiment with a less intrusive menu design in comparison to group one. A sidebar, as the name suggests, lies on the side of the screen and not at the focus. Thus, it does not cover any of the tutorial text.

By hovering over a text passage that can be influenced by modifying a specific parameter, the passage is highlighted in the same frame colour of the parameter in the sidebar. We used this colour-coded highlighting method for simplification purposes and due to the technical limitations of Adobe XD.

Version Three

As figure 4.3 shows, the button *Show Spin-offs* was placed in this prototype version at the top of the tutorial page. By clicking on it, a sidebar appears as described above. The sidebar contains all parameters relevant for all spin-offs regarding the whole tutorial.

Project-based spin-offs with a sidebar menu.

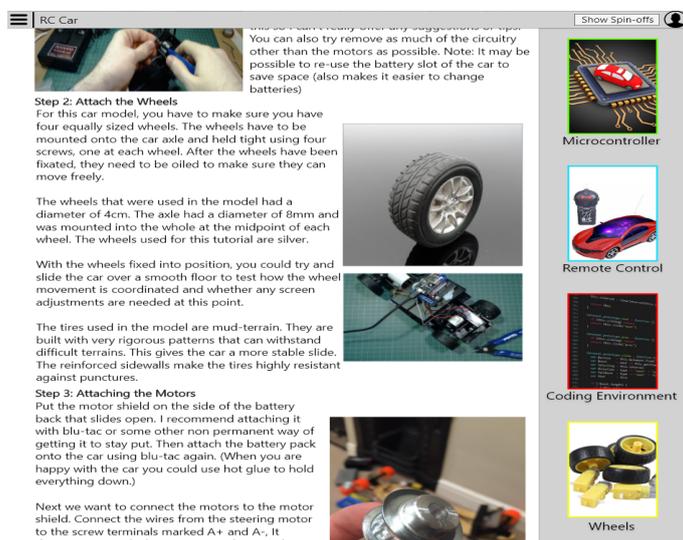


Figure 4.3: Version three for showing spin-offs. The button to show spin-offs is placed at the top of the tutorial page. Spin-offs appear as a sidebar. Images from L.R.T.B: [11,20,3,5,12,7,13,6], text based on [27].

Version Four

Step-based spin-offs with a sidebar menu.

Using the same sidebar described above, we experiment in this prototype by placing the button *Show Spin-offs* directly next to each step, instead of placing it at the top of the tutorial page. Figure 4.4 shows the sidebar that appears by clicking on the button *Show Spin-offs* located next to the second step. The parameters, and accordingly the spin-offs, that are included in the sidebar are limited to the specific step where the *Show Spin-offs* button was clicked.

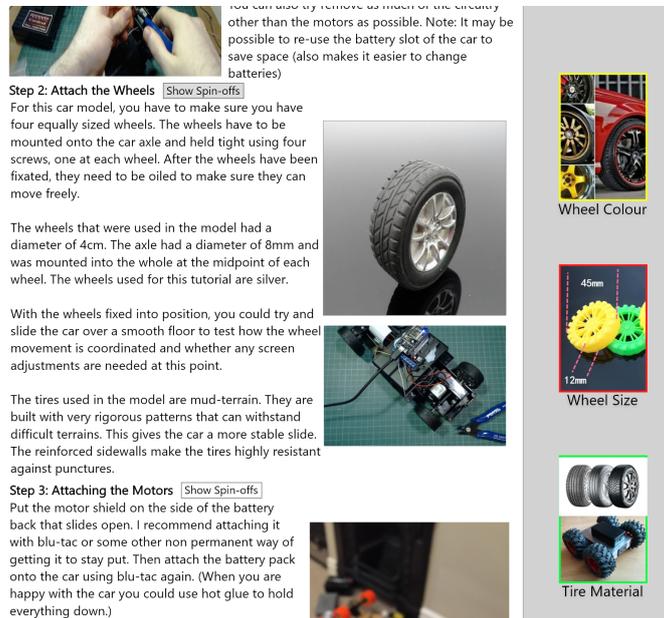


Figure 4.4: Version four for showing spin-offs. The button to show spin-offs is placed next to each step. Spin-offs appear as a sidebar. Images from L.R.T.B: [11,28,3,1,12,18,17,13], text based on [27].

Group Three

This group consists of only one prototype. Instead of having a menu, we wanted to experiment here with using a wizard for selecting the spin-offs.

Version Five

Using this prototype version, makers can use a wizard to select the spin-off for each of the project parameters. Figure 4.5 shows the selection wizard. For each parameter, the user is presented with a list of spin-offs. From that list, the user can choose the spin-off to be applied. Once a spin-off for a specific parameter has been selected, the nodes at the upper part of the wizard are updated to reflect the user's choice.

Choosing spin-offs through a wizard.

Each node in the upper part of the wizard represents a chosen spin-off. The edges joining between the nodes are labelled with the name of the parameter. For example, the spin-off *Arduino Uno* was chosen for the parameter *Microcontroller*.

Tracking chosen spin-offs in the wizard box.

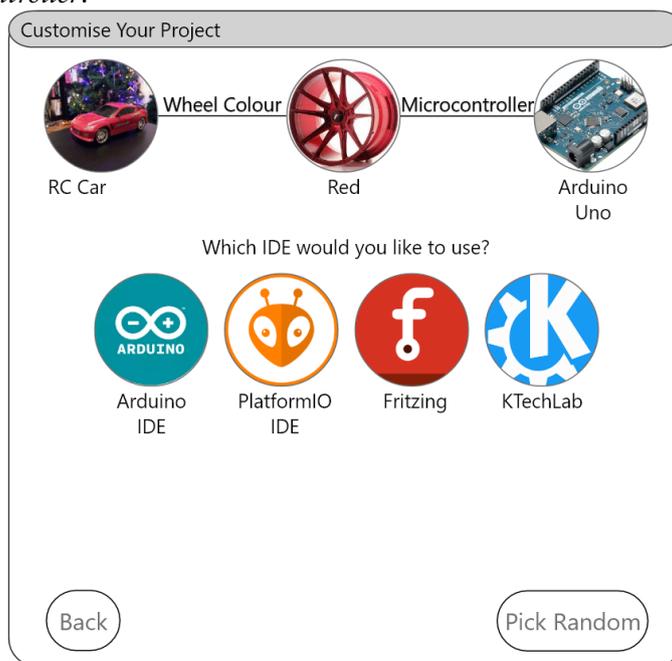


Figure 4.5: Version five for showing spin-offs. Spin-offs can be chosen through a wizard. Images from L.R.T.B: [14,16,9,23,22,24,15].

Using the wizard, users can experiment with random constellations of spin-offs. By clicking on *Pick Random* as shown in figure 4.5, a random spin-off will be selected for

Create random constellations of parameters.

the given parameter.

Using the wizard could make it easier to make bigger changes to the project.

An advantage we saw in this prototype version in comparison to the rest of the prototypes, is that users can make changes that address multiple parameters at once. This could be especially useful in case of wanting to make bigger changes to the project that would require manipulating several parameters.

This wizard can be accessed through a button we labelled as *Customise Project*. This button was located at the top of the project page. We chose to call the button *Customise Project* because this prototype version allows its users, as described above, to customise multiple parameters of the project at once.

Group Four

Using a carousel to show the spin-offs.

Both prototypes in this group have the button to show spin-offs located next to each step. The difference between the two versions lies in the location of the spin-offs menu that appears when that button is clicked. We wanted to experiment with a menu design that is neither as intrusive as group one, nor as recessive as group three. We will be discussing the design of the menu in the next two prototypes.

Version Six

Showing the spin-offs in a lower carousel.

As for this prototype version, we experiment with showing spin-offs in form of a carousel menu that appears at the bottom of a step once the button *Show Spin-offs* has been clicked. The reason why we placed the carousel at the bottom of the step, is to not disturb the user's reading flow when the button *Show Spin-offs* is clicked. Figure 4.6 shows how this carousel looks like. For that figure, the button *Show Spin-offs* next to the second step was clicked.

Hovering over any of the parameters in the carousel would highlight the text passage, that would change by altering

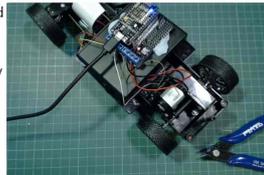
Step 2: Attach the Wheels[Show Spin-offs](#)

For this car model, you have to make sure you have four equally sized wheels. The wheels have to be mounted onto the car axle and held tight using four screws, one at each wheel. After the wheels have been fixated, they need to be oiled to make sure they can move freely.

The wheels that were used in the model had a diameter of 4cm. The axle had a diameter of 8mm and was mounted into the hole at the midpoint of each wheel. The wheels used for this tutorial are silver.

With the wheels fixed into position, you could try and slide the car over a smooth floor to test how the wheel movement is coordinated and whether any screen adjustments are needed at this point.

The tires used in the model are mud-terrain. They are built with very rigorous patterns that can withstand difficult terrains. This gives the car a more stable slide. The reinforced sidewalls make the tires highly resistant against punctures.

**Step spin-offs**

Tire Material



Wheel Size



Wheel Colour

Figure 4.6: Version six for showing spin-offs. Spin-offs can be chosen from a carousel. Carousel lies at the bottom of the step. Button to show spin-offs is located next to each step. Images from L.R.T.B: [3,12,10,8,21], text based on [27].

that parameter. In the case of figure 4.6, the user is hovering over the parameter *Wheel Size*. If needed, users could scroll in the carousel to the right to view further parameters.

Version Seven

Since the carousel appears in prototype version six at the bottom of the step, a potential problem that users could face, is that the carousel might not be directly visible depending on the user's screen size, scroll position and the length of the step. A potential solution is to show the carousel at the top of the step instead of at the bottom. Figure 4.7 shows how the carousel looks like.

Showing the spin-offs in an upper carousel.

All further details regarding the functionality of the carousel remain analogous to the above-mentioned described in prototype version six.

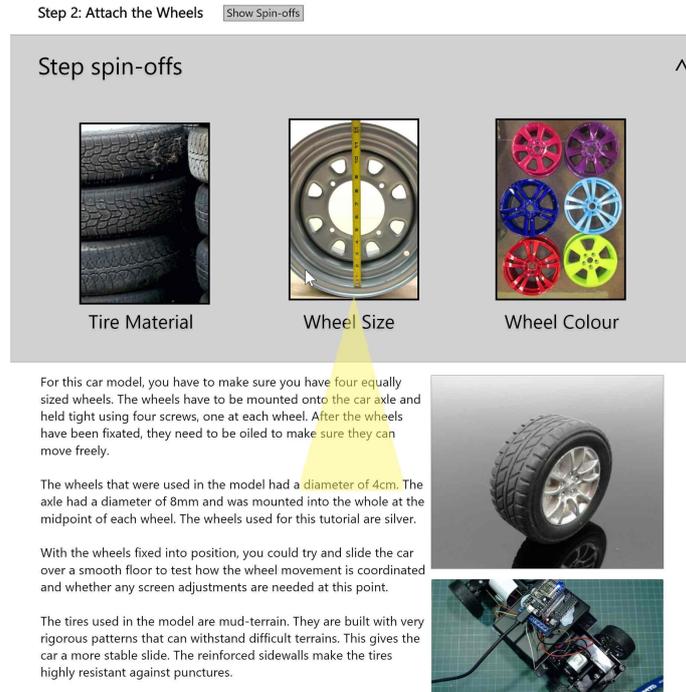


Figure 4.7: Version seven for showing spin-offs. Spin-offs can be chosen from a carousel. Carousel lies directly under step title. Button to show spin-offs is located next to each step. Images from L.R.T.B: [10,8,21,3,12], text based on [27].

Changes Confirmation Page

After a spin-off has been selected, the user is presented with a *Spin-off Changes* screen where the changes between the original version and the spin-off are highlighted. Figure 4.8 shows how these changes are highlighted. The left half of the screen depicts the original version, while the right half shows the spin-off. For each step with a modification, the changes are highlighted. Once the user confirms the spin-off choice, the user is moved to a tutorial page where the spin-off is accordingly applied.

The functionality of the confirmation page for spin-offs.

This confirmation page applies to all of the above men-

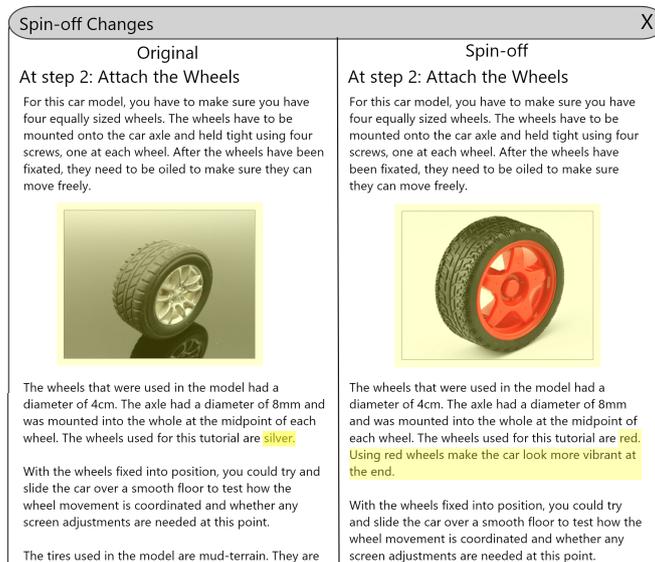


Figure 4.8: Changes between the currently displayed version and the spin-off are highlighted. Images from L.R.T.B: [3,25], text based on [27].

tioned prototype versions with the exception of prototype version five. Users can utilise the wizard in version five to alter multiple parameters at once and thus make bigger changes at the project. The connected nodes at the top of the wizard screen show the chosen spin-offs. For these reasons, prototype version five does not feature an additional confirmation page.

Different Button Placements

We tested in the above-mentioned prototypes two different placements of the *Show Spin-offs* button: one was placed next to each step, and the other at the top of the tutorial page. The benefit we saw in placing the button next to each step is to limit the number of displayed parameters when the button is clicked, thus making it potentially easier for makers to find the spin-off they are seeking. Furthermore, the parameters are limited to the ones that appear in the respective step.

Potential benefit of placing *Show Spin-offs* button next to the steps.

Potential benefit of placing *Show Spin-offs* button at the top of the project page.

The alternative was to place the *Show Spin-offs* button at the top of the tutorial page. Placing the button only once at the top of the page, instead of next to each step, could help in potentially making the tutorial page look less cluttered. A further advantage is that some spin-offs could potentially change parameters that influence multiple steps. The placement at the top of the page could also help make it clearer to the users that spin-offs are not always just limited to a certain step, but could influence other steps as well.

4.2 Creating Spin-off

An integral part of the spin-offs concept is giving the users the option to contribute to pre-existing projects, by creating their own spin-offs. We will be discussing in this section two prototype versions that demonstrate how makers can create spin-offs.

Version One

Creating spin-offs based on pre-existing projects.

For makers to create a spin-off, they can click on a button called *Create Spin-off* placed on the top of the tutorial page. Users remain on the same screen when they click on that button, only the structure of the tutorial page slightly changes. As figure 4.9 shows, users get the option to add a new step in-between two pre-existing steps. Users also get the option to delete a step completely.

The text, as well as the multimedia material associated with each step, can be modified using an in-place text editor. Makers also have the freedom to rename the steps. After all needed changes for the spin-off creation have been made, users can click on *Save* to proceed further.

Specifying changed parameters for the newly created spin-off.

Figure 4.10 shows the pop-up that appears once the *Save* button has been clicked. On that screen, users can give their new spin-off a title. For each of the steps where a change has been made, users have to specify the parameters that

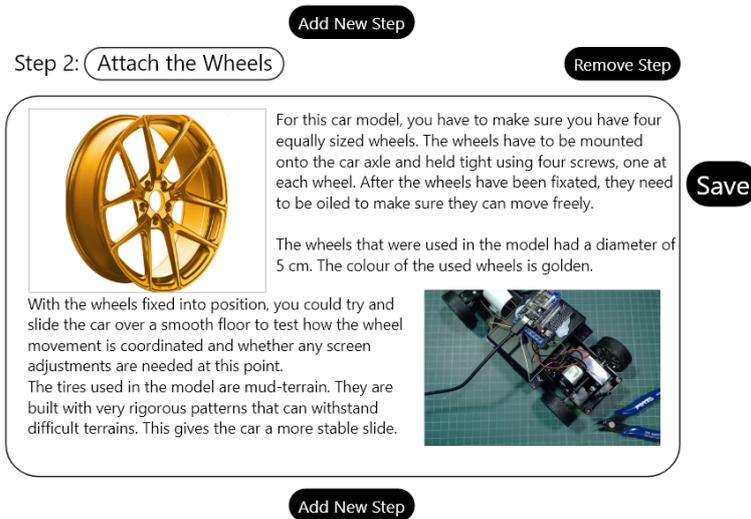


Figure 4.9: Prototype for creating spin-offs. Makers can edit, remove or add new steps. Images from L.R.T.B: [2,12], text based on [27].

were influenced. In case a parameter does not exist, users have the option to potentially create it.

Spin-off Creation X

Spin-off Title

Changed Parameters
At step 2: Attach the Wheels ▼

Preview Image
+
Upload an Image

Next

Figure 4.10: Prototype for creating spin-offs. Form for entering created spin-off information.

After all the information has been entered, users can click on *Next* to move to a preview page of their spin-off. Once

Publishing newly created spin-off.

the users have reviewed the information on the preview page, they can publish their spin-off. The newly created spin-off can now be viewed by other makers.

Version Two

Binding created spin-offs to selected text.

Using this prototype version, makers can create a spin-off that they bind to a specific word, sentence or passage of the tutorial. To achieve this, makers have to select the sentence or the passage, to which they want to bind the spin-off, before proceeding with creating the spin-off. By doing so, we give the users control over how their created spin-off is shown to other users.

Users are notified to select text to create a spin-off.

In prototype version one, the created spin-off is bound to every step where a change has been made. In this version, the created spin-off is bound only to the selected text. As figure 4.11 shows, the user is notified in a tooltip to select a text before a spin-off can be created. The button *Create Spin-off* is greyed out because no text is selected.

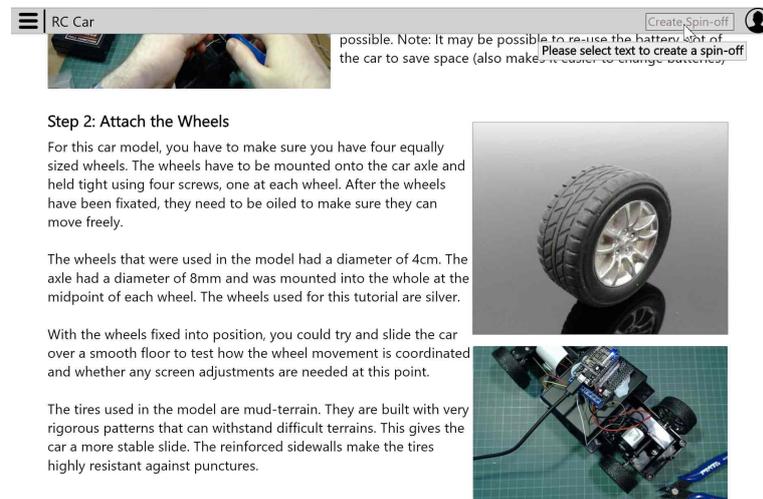


Figure 4.11: Prototype for creating spin-offs. Text has to be selected before a spin-off can be created. Images from L.R.T.B: [11,3,12], text based on [27].

Other than the above-mentioned difference, this prototype version behaves analogously to prototype version one.

Chapter 5

Study

As discussed in Kuznetsov and Paulos [2010], maker documentation platforms are built around the idea of free knowledge sharing with low barriers to entry and a focus on collaboration and creativity. To encourage collaboration on maker platforms, we proposed in chapter three the idea of spin-offs. We further developed prototypes for this idea in chapter four.

In this chapter, we would like to evaluate the prototypes we created. We also want to evaluate how creating and viewing spin-offs could potentially affect makers' experience on maker platforms. For that, we conducted a user study using the prototypes we developed. Results of this study will be used to draw design implications accordingly.

Investigating how spin-offs could improve makers' experience on DIY platforms.

5.1 Task-Oriented User Study

5.1.1 Aims

The goal is to evaluate the prototypes we created. These prototypes demonstrate how makers can create or show spin-offs. Specifically, we want to compare the evaluated prototypes against each other. Based on our results, we

How do makers perceive spin-offs?

want to gain a better understanding of the makers' design preferences regarding the spin-off feature.

5.1.2 Research Questions

We intend to answer the following two research questions:

RQ1 In case of spin-off viewing prototypes, how do versions one to seven compare against each other in terms of the time the users need to view spin-offs (t), the user preferences ($rank$) and the number of misclicks the users make, while trying to view the spin-offs ($misclicks$)?

RQ2 In case of spin-off creation prototypes, how do versions one and two compare against each other in terms of the time the users need to create spin-offs (t), the user preferences ($rank$) and the number of misclicks the users make, while trying to create the spin-offs ($misclicks$)?

5.1.3 Hypotheses

Corresponding to the above-mentioned research questions, we construct the following hypotheses. We state them in their null form.

H_0^1 In case of spin-off viewing prototypes, there is no significant difference based on the prototype version for t .

H_0^2 In case of spin-off creation prototypes, there is no significant difference based on the prototype version for t .

H_0^3 In case of spin-off viewing prototypes, there is no significant difference based on the prototype version for $rank$.

H_0^4 In case of spin-off creation prototypes, there is no significant difference based on the prototype version for $rank$.

H_0^5 In case of spin-off viewing prototypes, there is no significant difference based on the prototype version for $misclicks$.

H_0^6 In case of spin-off creation prototypes, there is no significant difference based on the prototype version for *misclicks*.

5.1.4 Study Variables

Independent Variable

As discussed in chapter four, we created multiple prototypes for the spin-offs feature. The independent variable of our study is:

- The prototype version number. This ranges from version one to seven in the case of prototypes regarding showing spin-offs. For the case of spin-off creation prototypes, the prototype version number is either one or two.

The independent variable is the version number of the prototype.

Dependent Variable

The choice of the dependent variables is based on the QUIM model as discussed by Seffah et al. [2006]. This model provides metrics for quantifying usability in HCI research. Specifically, these dependent variables were chosen to answer the research questions and examine the hypotheses.

In the following, we use n to refer to the number of the participants. Each of the participants will complete tasks on p different prototypes. The tasks will be described in the next subsections. We define the following dependent variables:

1. Number of misclicks with the following measurement function:

$$\text{misclicks}(n_i, p_j) := \text{number of misclicks user } n_i \\ \text{made in prototype } p_j \quad (5.1)$$

Counting misclicks as a dependent variable in our study.

A click is counted as a misclick, when it does not lead to any further progression regarding the given task to user n_i on prototype p_j . There is only one way to complete a task on a given prototype. In case a user was proceeding correctly in a task, yet broke the procession at some point, all clicks that would lead the user back to the point, where the correct procession was broken, would be counted as misclicks. A perfect score of 0 indicates that the user made no misclicks. There is no fixed upper limit.

2. Completion time of task on prototype p_j for user n_i

$$t(n_i, p_j) := \text{time participant } n_i \text{ took to successfully} \\ \text{complete the task of prototype } p_j \quad (5.2)$$

Measuring the time taken to complete the tasks as a dependent variable.

We begin with measuring the time, once we have sent and completely read the task to the user. In case the user begins with the task, before it was completely read or sent to them, we would begin the time measurement with the first mouse click. We measure the time until the task has been completed. A task is completed, once the user has reached the designated final screen for that task on prototype p_j . To accurately assess the prototypes, we measure in t only the raw time a user took to complete the task. Thus, we subtract the time the user takes to give feedback or ask questions, in case this happens while completing the task. The time was measured in seconds. To measure the time, we used the stopwatch program, that comes pre-loaded on Windows 10.

We asked participants to rank the prototypes they used.

3. We asked the participants to create a subjective ranking of the prototypes from the most to the least favourable. The most favourable prototype was assigned the number one—as in first place, the least favourable was assigned the maximum number—as in last place. The maximum number is either seven, in the case of prototypes regarding showing spin-offs, or two, in the case of prototypes regarding creating spin-offs.

$$\text{rank}(n_i, p_j) := \text{position of prototype } p_j \\ \text{according to the ranking of participant } n_i \quad (5.3)$$

5.1.5 Tasks

The participants performed tasks that involved viewing and creating spin-offs on different prototype versions. The prototypes show a tutorial on how to build a remote-controlled car.

For all prototypes handling viewing spin-offs with the exception of prototype version five, users were given the following task:

For the given tutorial showing how to build a remote-controlled car, navigate to the spin-off of step two that shows the wheels in red instead of silver.

For prototype version five, the task was:

For the given tutorial showing how to build a remote-controlled car, navigate to the spin-off that shows the wheels in red, uses the microcontroller Arduino UNO and the development environment PlatformIO IDE.

After the first completion of the above-mentioned task, we briefly asked the participants to explain what they thought a spin-off was in their own words. In case the explanation was correct, we move on with the next task. We asked follow-up questions in case the participant's answer was not clear. If the participant's answer was wrong, we would reveal what a spin-off is. We asked this question to make sure the participants understood what the point of spin-offs is. We did this to ensure the validity of the feedback we get from the participants.

Starting from the second prototype the users evaluated, we asked the participants to rank the prototype version they have seen from the most to least favourable according to their subjective preference. We asked the participants to tell the reason for their ranking decision.

For the two prototypes handling how to create spin-offs, we gave the participants the following task:

The participants tested the different prototype version for creating and showing spin-offs.

We asked the participants to explain what they thought a spin-off is.

We asked the participants to rank the spin-off showing prototypes.

For the given tutorial showing to build a remote-controlled car, create a spin-off where the colour of the wheels is golden instead of silver, and the diameter of the wheels is five instead of four cm.

The participants were asked to explain what they thought they achieved by creating a spin-off.

After completing the task for the first time, we asked the participants to tell in their own words what they achieved by creating a spin-off. In case the explanation was correct, we would proceed with the next task. If the answer was unclear, we would ask follow-up questions. We would reveal the point of creating spin-offs in case the user's answer was wrong. We did this to ensure the participant's feedback was valid.

We asked the participants to rank the spin-off creation prototypes.

Once the users have completed the above-mentioned task on both spin-off creation prototypes, we would ask the users to rank the two prototypes according to their subjective preference. The participants are asked to reason why they preferred a specific prototype version over the other.

5.1.6 Experimental Design and Procedure

Fourteen participants took part in the study.

The study was completed by 14 participants. Prior to the study, potential candidates were asked to fill in a *background information questionnaire* as shown in appendix C. Among others, they were asked about how many online DIY projects they followed or published within the last two years. We only invited the candidates to take part in the study, that answered the previously-mentioned question with at least *one project*. We did this for the sake of validity and relevancy of the study participants' feedback. Participants did not receive compensation for taking part in this study.

In a within-subject study design, we made a total of 196 trials.

A within-subjects design was used for the study. We used a balanced Latin square as described in Bradley [1958] to counterbalance carryover effects and avoid other unknown or unwanted factors based on the order of the prototypes. For an odd number of columns—here the prototype versions, the structure of the generated Latin squares requires twice as many rows to be balanced. Since we have seven prototypes for showing spin-offs, the balanced Latin square

was composed of 14 rows. Each row stood for one participant. Regarding spin-off creation prototypes, half of the participants tested version one before two, the other half two before one. The balanced Latin square is attached in appendix E. In summary, the collected data was: 14 participants \times 7 spin-off viewing prototypes \times 2 spin-off creation prototypes = 196 total trials.

The study took place online as a conference call with enabled screen-sharing. Participants were invited to the conference call on Zoom¹, for which they receive the access link in advance. Users were asked to turn on their audio feed as well as share their screen. Participants were invited to turn on their video feed, if they feel comfortable about it. In case of using multiple screens, participants were asked to share the screen, that they will be using to run the prototypes. As discussed, the prototypes were created on Adobe XD. We shared the link to the prototypes with the users via Zoom chat. The landing page was the “Alive Documentation”-artboard.

For the Zoom call to take place, participants need to be connected to the internet and have a working microphone. Participants also need to have a recent version of the conference software Zoom installed on their computer. To view the prototypes, participants need to have a modern browser² version of Safari, Chrome, Firefox or Edge installed. In case the conference call will be recorded, we have to make sure that there is at least 2 GBs of free disk space on the drive where the recording is saved. The device we used during the study was running on Windows 10.

The procedure of the study can be divided into two sections:

Prior to the Session The first stage in the study was to screen the potential participants by sending the attached *Participant Background Questionnaire* in C. Due to the digi-

¹<https://zoom.us> (Accessed: 06.09.2021)

²Further information regarding supported browser versions can be found on <https://helpx.adobe.com/no/xd/system-requirements.html> (Accessed: 06.09.2021)

The study took place on Zoom.

We tested the prototypes we created using Adobe XD in this study.

To measure t , we used the stopwatch program on Windows 10.

We screened the participants first to ensure whether they qualified.

tal nature of the study and to facilitate the fill-in process, we designed the background questionnaire as a digitally fillable PDF document.

According to the answers received by the potential participant, we would verify whether they lie within the predefined target group according to the *participants* section. We proceeded with the participant if their answers fit.

We sent qualifying participants the Zoom conference link as well as the informed consent form.

Next is to set up an appointment with the participant. Once done, we would send the participant the Zoom conference link as well as the informed consent form. To facilitate the creation of the Zoom conference link, we used our Zoom permanent personal link³. According to how the communication with the participant was established, we would either send this information in an E-Mail or in a chat message on the platform where we first contacted the participant. As we will discuss later in this subsection, we set the session to allow using annotation tools⁴.

We welcomed the participants and told them about the goal of the study as well as the dependent variable we would be testing.

During the Session At the scheduled meeting, we would commence the call by welcoming the participant to the study and thanking them for their time. We would then proceed by briefly describing the purpose of the study as described in the *aims* subsection. We would then tell the participant that we were measuring the time they took to complete the tasks as well as the number of misclicks they made. We asked them thus, as much as they could, to aim for the direct way to complete the tasks.

In case the session was planned to be recorded, we would inform the participant that we would start the recording. Once the recording has been started, we would briefly welcome the participant and repeat the purpose of the study on record.

The next step is to tell the participant that the purpose of the study is to test the the proposed prototypes, not their

³<https://support.zoom.us/hc/en-us/articles/201362843> (Accessed: 06.09.2021)

⁴<https://support.zoom.us/hc/en-us/articles/115005706806> (Accessed: 06.09.2021)

knowledge. We told the participant that it was okay to make mistakes or ask questions. We then proceeded to tell the participant that the study follows a think-aloud protocol, so we would expect them to tell us what they were thinking while they were completing the tasks. We told the participants this to make sure the participants are feeling comfortable during the session as well as to encourage them to actively share their opinions and thoughts with us.

The purpose of the study is to test the prototypes, not the participant's knowledge.

Next is to let the participant know that all collected data will be made anonymous. We informed the participant about their right to ask for all the collected data to be shared with them. If they wanted to, they could also ask for the data to be deleted. We informed the participants that they could ask to take a break at any time during the session.

All collected data will be made anonymised.

We asked the participant at this point to open a supported browser as previously described, preferably in incognito mode. The participants were then asked to share their screen with us, preferably only the incognito browser window they opened. To be able to track the participant's mouse clicks, we asked the participant to go to the Zoom ribbon that appeared when the screen was shared and click on *annotate*, then *spotlight* and select the first option on the left to turn the mouse cursor into a red pointer. Figure 5.1 shows where this setting is located.

To track misclicks, we asked the participants to turn their cursor into a red pointer using Zoom's annotation tools.



Figure 5.1: Option to turn mouse cursor into a spotlight on the Zoom ribbon when the screen is being shared.

With the *pointer spotlight* option activated, clicks can be tracked as the size of the red dot changes when a click is made. To be able to audibly track the clicks as well, we asked the participants to place their mouse as near as they could to the microphone. We would ask the participant to make random mouse clicks to ensure that the visual tracking is working correctly. Audibly tracking mouse clicks is preferable, but not mandatory.

We asked the participants to place their mouse near to the microphone so we can audibly track mouse clicks as well.

We proceeded at this point by sending the participant the

We sent the participants the link to the Adobe XD prototypes.

link to the prototypes on Adobe XD. We asked the participant to load the link in the browser they had opened. Once the link has been opened, we would ask the participant to click on *Showing Spin-offs*.

The participants were asked to perform predefined tasks on the prototypes.

We repeated these steps for all the prototypes concerning showing spin-offs. The tasks the participants performed are described in the subsection *tasks*. The order of the prototypes followed the attached balanced Latin square in appendix E.

1. Ask the user to click on the prototype version they will be testing.
2. Read the task aloud to the participant.
3. Send a written copy of the task via Zoom chat.
4. Take notes and do the measurements as previously described, while the participant is completing the task.
5. If the user is asked to rank the prototype as described in the subsection *tasks*, wait for their answer and then send them a chat message via Zoom that shows using the relation $>$ a chain from the most to the least favourable prototype until now.
6. Ask the user to scroll to the bottom of the screen and click on *back*

The reason we sent that ranking chain as described in step five, was to help the participants keep track of their previous rankings.

The same above-mentioned steps were repeated for spin-of creation prototypes.

Once the previous steps have been completed for all prototypes concerning showing spin-offs, we would ask the participant to click on *Back* and then on *Creating Spin-offs*.

The next step was for us to repeat the above-mentioned steps for the two spin-off creation prototypes.

This marks the end of the task-oriented user study. We proceeded further at this point as described in the following section *Semi-Structured User Interview and Questionnaire*.

5.2 Semi-Structured User Interview and Questionnaire

The goal of the semi-structured interview was to gain further insight into how the participants perceived the prototypes they saw, and which versions they preferred. We also asked the participants to share their ideas on other ways to view or create spin-offs. The predetermined questions we asked are attached at appendix B. We asked follow-up questions in case the participants' answers were not clear. Based on the answers, we would ask, if required, further questions to better understand how the prototypes were perceived. The interview was meant to take about five minutes.

We asked further questions in the interview based on the participants' answers.

After the interview, we would send the participant a questionnaire on Likert scale as shown in appendix A. The goal of the questionnaire was to understand how spin-offs were perceived as a concept and whether the participants saw any potential benefit in using them either as authors (spin-off creators) or as community members (spin-off viewers). We sent the questionnaire via Zoom chat as a PDF file. The participants were asked to open the questionnaire in a PDF viewer of their choice, preferably in the browser where they had completed the tasks on the prototypes. We reminded the participants that we were interested in their verbal feedback and asked them to share their thought process with us while answering the questions.

The questionnaire was on Likert scale.

After completing the questionnaire, we asked the participants to let us know if they had any final comments, ideas or thoughts they wanted to share with us. We would then proceed to thank the participants for their participation in the study.

Finally, we would stop the recording, in case the session was being recorded. For future evaluation, we would then ask the participant to send the filled-in questionnaire back to us. In case the participant has not sent it already, we would ask the participant to turn in their consent form as well. We then proceeded to thank the participant again, bid them goodbye and ended the Zoom call.

At the end, we thanked the participants and ended the Zoom call.

Chapter 6

Results

In this chapter, we analyse the data we collected per to the study described in chapter five. A total of 14 participants (21-61 years, $M=30.06$, $SD=10.34$) took part in the study. As described before, only participants took part in the study, that have completed at least one project within the last two years (Total number of completed projects: 2-32 projects, $M=10.57$, $SD=8.32$ - Total number of authored projects: 0-10 projects, $M=1.57$, $SD=2.69$ - Projects authored or completed within the last two years: 1-17 projects, $M=5.11$, $SD=3.86$).

The 14 participants in the study had a mean age of 30.06 years.

One participant failed to complete the task on one of the spin-off creation prototypes. For the sake of comparability of the results, we struck out the participant's collected quantitative data concerning spin-off creation. We retained the qualitative data though, to analyse it for potential reasons for why the participant could not complete the task.

The call with another participant was disrupted during the second half of the post-study questionnaire. We resumed the call on the following day. In the follow-up call, we re-sent the participant the link to the prototypes, so that the participant could recheck them if needed. The participant confirmed that they still remembered all the details needed to answer the questions. Thus, we retained the data collected from that participant.

6.1 Quantitative Data Analysis

We analyse in this section the data we collected. This section is divided into subsections, where we present the data regarding each of the previously introduced dependent variables.

6.1.1 Time Taken: t

Spin-off Showing Prototypes

Prototype version
has the lowest
arithmetic mean and
median in t .

Figure 6.1 shows a box plot of the seven spin-off showing prototypes, labelled as $s1$ to $s7$. Prototype version four witnesses the lowest median. As the figure shows though, there is not much difference in the medians of the first five prototypes. Version four also has the lowest arithmetic means as indicated in table 6.1.

Box Plot of Completion Time

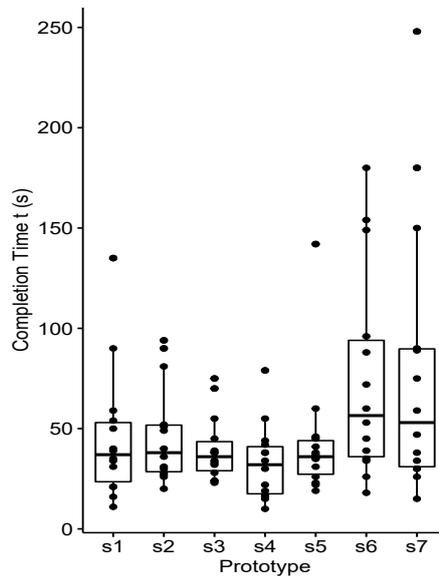


Figure 6.1: Box plot of completion time for showing spin-off prototypes.

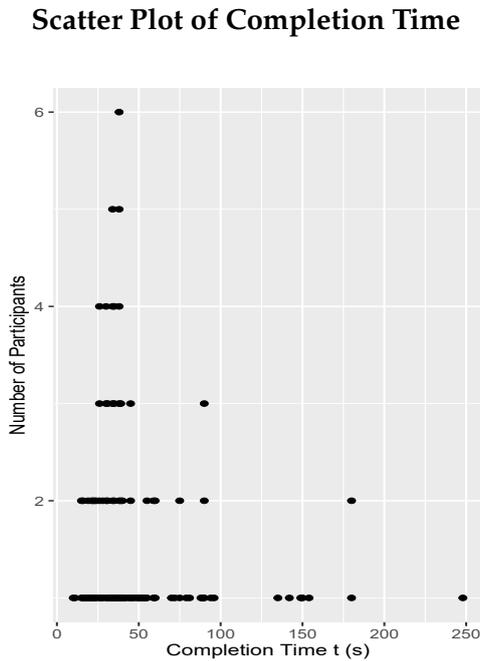


Figure 6.2: Scatter plot of completion time to the number of participants for showing spin-off prototypes. Plot suggests a lognormal distribution.

A scatter plot of the completion time to the number of participants suggests a lognormal distribution as shown in figure 6.2. As discussed by Jensen [1991], the use of the geometric mean rather than the arithmetic mean is encouraged for lognormally distributed data. The geometric mean of version four is the lowest as shown in 6.1.

Version four also has the lowest geometric mean of t .

Prototype	Geometric mean	Arithmetic mean	SD
s1	36.89	45.43	32.88
s2	41.63	46.79	24.66
s3	37.21	39.86	16.36
s4	28.21	32.79	18.76
s5	37.18	42.86	30.57
s6	59.98	74.93	52.03
s7	58.15	81.5	68.43

Table 6.1: Arithmetic and geometric mean as well as SD of t in spin-off showing prototypes.

To test for significance, we wanted to conduct a one-way

Data regarding t is not normally distributed.

repeated measures ANOVA. As figure 6.3 shows, the data is not normally distributed. To analytically confirm this, we conducted the Shapiro-Wilk's test. As table 6.2 shows, $p < 0.05$ at all prototype versions except s4. For that reason, we applied a logarithmic transformation to the data to better fit normal distribution.

QQ Plot of Completion Time

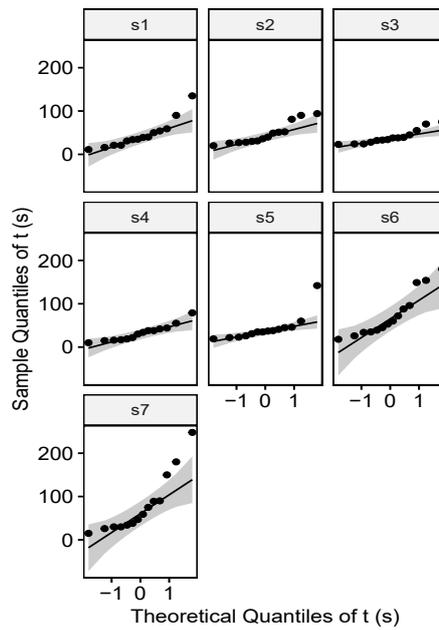


Figure 6.3: Quantile-quantile plot of completion time in spin-off showing prototypes. Data is not normally distributed.

Prototype	p before transformation	p after transformation
s1	0.0112	0.996
s2	0.0187	0.299
s3	0.0274	0.305
s4	0.155	0.913
s5	0.00008	0.086
s6	0.0422	0.843
s7	0.00919	0.845

Table 6.2: Shapiro-Wilk's test for normal distribution of completion time in spin-off creation prototypes.

Figure 6.4 indicates, the logarithmically transformed data

can be assumed as normally distributed. To analytically confirm that result, we conducted the Shapiro-Wilk's test again on the transformed data. As table 6.2 shows, the test confirms the graphical results ($p > 0.05$ for all prototype versions).

Data can be assumed as normally distributed after logarithmic transformation.

QQ Plot of Completion Time

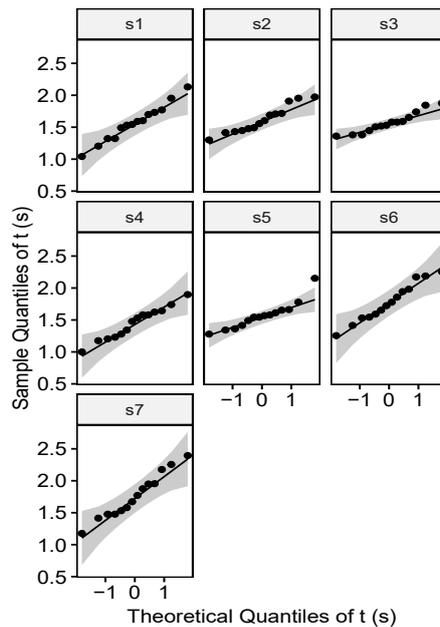


Figure 6.4: Quantile-quantile plot of logarithmic completion time in spin-off showing prototypes. Data is normally distributed.

The logarithmically transformed data was not found to have any significant outliers as shown in figure 6.5. We applied the sphericity correction of Greenhouse-Geisser to factors violating the sphericity assumption.

ANOVA can be used on the logarithmically transformed data.

By applying the ANOVA test to the transformed data, the completion time t was found to be significantly different for the different prototype versions ($F_{6,78}=3.55$, $p=0.004$). To identify the significantly different pairs, we conducted a post hoc test using pairwise paired t-tests with the Holm correction method to adjust p . Prototypes version four and six were found to be significantly different ($p < 0.05$). Figure 6.5 shows the results of the ANOVA and the post hoc

There is a significant difference in t between version four and six, thus we reject H_0^1 .

QQ Plot of Logarithmic Completion Time

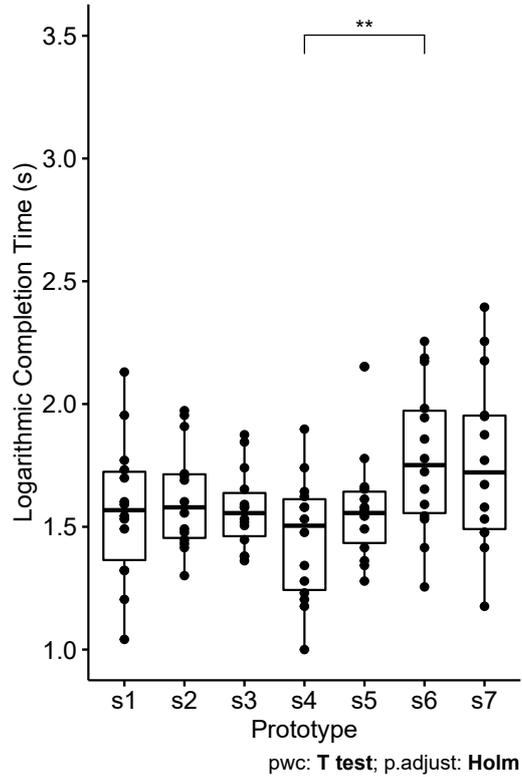


Figure 6.5: ANOVA test indicates significant difference in completion time. Post hoc shows significant difference between prototype version four and six.

test. Based on this, the hypothesis H_0^1 can be rejected, which stated no significant difference based on the used prototype in showing spin-offs with regards to completion time t .

Spin-off Creation Prototypes

The arithmetic mean of t in prototype one was slightly less than two.

We created a plot of the means to compare the first spin-off creation prototype (c1: $M=89.84$, $SD=62.34$) with the second one (c2: $M=104.77$, $SD=42.39$). As figure 6.6 shows, the mean completion time of prototype one is slightly lower

than prototype two.

Completion Time t of Spin-off Creation Prototypes

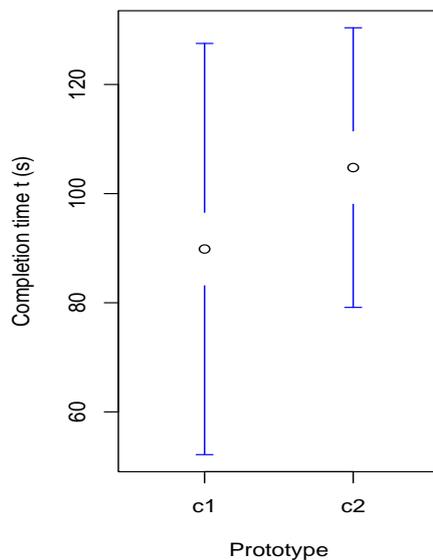


Figure 6.6: Mean completion time t with 95% CI of the spin-off creation prototypes.

To further analyse the data for the presence of a significant difference, we conducted a paired sample t-test to compare the two prototypes. The two-tail p was 0.52, which is higher than the significance level of 5%. That implies there is no significant mean difference between the two prototypes. Thus, we can not reject the hypothesis H_0^2 .

Due to the absence of a significant difference, H_0^2 can not be rejected.

6.1.2 Number of Misclicks: *misclicks*

Spin-off Showing Prototypes

As table 6.3 shows, prototype version four has the lowest arithmetic mean of the number of misclicks between the spin-off showing prototypes. Figure 6.7 shows in a box plot the number of misclicks for each prototype. The medians of the first five prototypes equal zero.

There is no difference in *misclicks* between the medians of the first five prototypes.

Prototype	Mean	SD
s1	1.09	1.85
s2	1.18	1.98
s3	0.45	1.00
s4	0.18	0.39
s5	0.45	2.86
s6	1.64	2.11
s7	1.09	3.26

Table 6.3: Arithmetic mean and SD of number of clicks in spin-off showing prototypes.

H_0^3 can not be rejected due to the absence of a significant difference in *misclicks*.

We conducted an analysis using the Friedman test to check for significant differences. Its results showed that there is no significant difference in the number of misclicks between the spin-off showing prototypes with $\chi^2(6)=6.87$ and $p=0.33$. Thus, we can not reject the hypothesis H_0^3 which states that there is no significant difference in the number of misclicks between the spin-off showing prototypes.

Misclicks of Spin-off Showing Prototypes

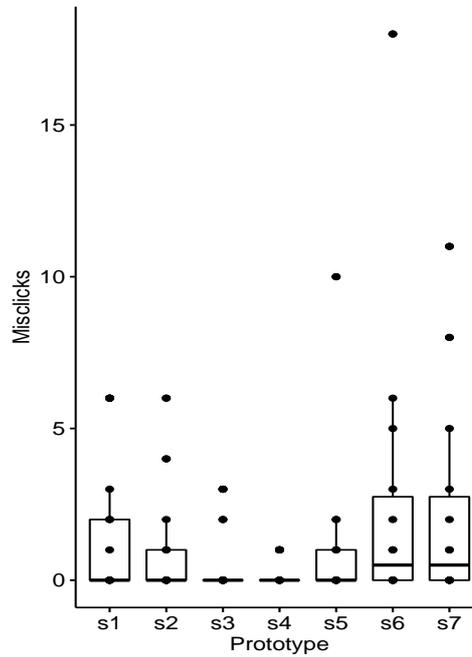


Figure 6.7: QQ plot of misclicks for spin-off showing prototypes.

Spin-off Creation Prototypes

Figure 6.8 shows a box plot we created to compare the first spin-off creation prototype (c1: $M=5.77$, $SD=13.78$) with the second one (c2: $M=5$, $SD=4.73$) in terms of *misclicks*. The mean number of misclicks of prototype one is slightly higher than prototype two.

The mean of misclicks in prototype one is higher than two.

Misclicks in Spin-off Creation Prototypes

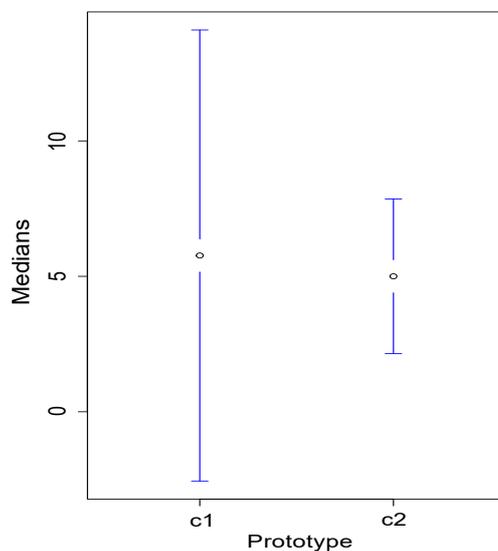


Figure 6.8: Mean misclicks with 95% CI of the spin-off creation prototypes.

We conducted a paired sample t-test to analyse the data for significant differences. The two-tail p is 0.81, which is higher than the significance level of 5%. That implies there is no significant mean difference between the two prototypes. Thus, the hypothesis H_0^4 can not be rejected.

H_0^4 can not be rejected due to the absence of a significant difference in *misclicks*.

6.1.3 User Ranking: *rank*

As discussed in the study chapter, we asked the participants to rank the prototypes according to their preferences. The most favourable prototypes received the highest rank-

ing of one, the least favourable prototype received either the ranking of seven in case of spin-off showing prototypes, or two in case of spin-off creation prototypes.

Spin-off Showing Prototypes

We began by analysing the arithmetic mean and SD of the rankings we collected regarding the spin-off showing prototypes. As table 6.4 shows, prototype version four has the lowest arithmetic mean, thus indicating the highest ranking.

The median of *rank* of version four was one, thus indicating high ranking.

Figure 6.9 shows a box plot of the showing spin-off prototypes regarding their ranking. The median value of prototype version four lies at one, the highest ranking.

Prototype	Mean	SD
s1	4.57	1.70
s2	5.86	1.23
s3	3.79	1.67
s4	1.64	1.01
s5	4.43	2.06
s6	4.36	1.98
s7	3.36	1.69

Table 6.4: Arithmetic mean and SD of rankings in spin-off showing prototypes.

H_0^5 can be rejected due to the presence of significant difference in *rank*.

To further analyse the data for the presence of a significant difference, we conducted a Friedman test. The test results indicate a significant difference between the rankings of the different prototypes with $\chi^2(6)=30.31$ and $p<0.0001$. Thus, we reject the hypothesis H_0^5 , which states that there is no significant difference between the rankings of the spin-off showing prototypes.

To identify the significantly different pairs, we conducted a pairwise Wilcoxon signed-rank test between groups with the Holm correction method to adjust p . The results reveal statistically significant differences in the rankings between s1 and s4 ($p=0.035$) as well as s2 and s4 ($p=0.022$).

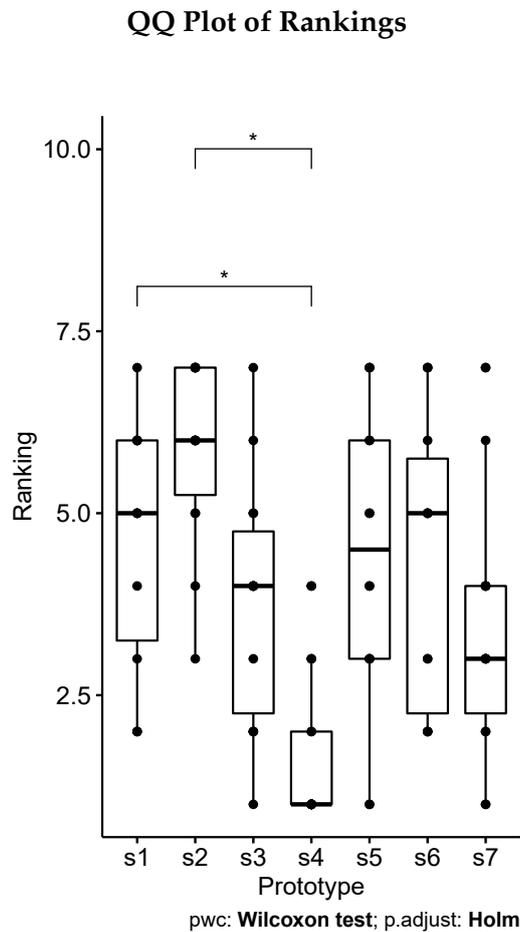


Figure 6.9: Friedman test indicates significant difference in rankings *rank*. Post hoc shows significant difference between prototype version one and four as well as two and four.

Spin-off Creation Prototypes

To analyse the data we collected regarding rankings of spin-off creation prototypes, we began by creating a plot of the means of the first (c1: $M=1.38$, $SD=0.51$) and the second (c2: $M=1.62$, $SD=0.51$) prototype. Figure 6.10 shows that the arithmetic mean of rankings for prototype version one is lower than version two, thus indicating a higher ranking.

For the sake of further analysis of the data regarding the

H_0^6 can not be rejected due to the absence of a significant difference in rank.

presence of a significant difference, we conduct a paired sample t-test. The two-tail p is 0.43, which is higher than the significance level of 5%. That implies there is no significant mean difference in the ranking between the two prototypes. Thus, we can not reject the hypothesis H_0^6 .

Mean Ranking of Spin-off Creation Prototypes

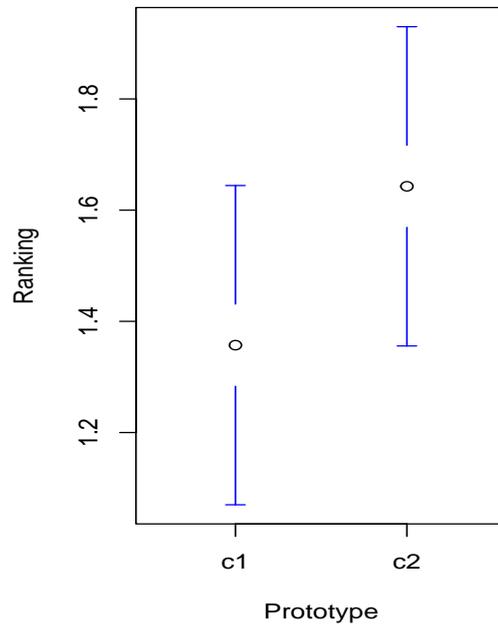


Figure 6.10: Mean ranking with 95% CI of the spin-off creation prototypes.

6.2 Discussion

In this section, we will be discussing the implications of the quantitative data analysis we presented in the last section. We will also be discussing the qualitative feedback that we received from the participants throughout the study and how it relates to the results of the quantitative data analysis.

As discussed in the study chapter, we asked the participant to complete a usability questionnaire. The questions as well as the results are documented in appendix A. All of the participants agreed or strongly agreed that using spin-offs would improve their experience with DIY platforms, with 78.57% of the participants saying they would frequently use the spin-offs feature themselves. 78.57% of the participants said that the spin-offs feature would motivate them to be more active makers. Results from the survey underscore potential benefits that the spin-offs feature could bring to makers.

Participants agreed that using spin-offs would improve their experience.

When asked whether they understood what spin-off means, 71.43% of the participants either agreed or strongly agreed with that statement. The rest of the participants said they were unfamiliar with the term and suggested using another name. When asked for suggestions, participants said using terms such as *personalise* or *customise project* could be more clear. One participant suggested renaming the button *Show Spin-offs* to *Show Alternatives* or *Show Variants*.

Most participants understood what *spin-off* means.

6.2.1 Spin-off Showing Prototypes

As discussed, a significant difference in the data was found in the case of the completion time as well as the ranking. Post hoc analysis showed the significant difference only existed in a strict subset of all the prototype pairs though. Thus, the results obtained through the significance analysis can not be directly used to draw a conclusion regarding the best performing prototype for each dependent variable.

Results from significance tests do not directly point out the best performing prototype.

Nevertheless, in the cases where a significant difference was determined, it was always between prototype version four and other versions. Since prototype version four performed best in terms of the arithmetic mean for all dependent variables, the post hoc tests show that prototype version four is significantly better performing than some other versions for specific dependent variables.

Prototype version four had the best arithmetic mean for all dependent variables.

Qualitative feedback we collected throughout the study

Overlay prototypes did not rank highly.	backs up version four. Compared to the other prototype versions, five participants praised the non-intrusive design used in prototype version four. Compared to other prototype versions where the spin-off menu appears as an overlay or as a carousel, prototype version four resorts to a side menu. This feedback especially supports the significant difference in the ranking, as discussed in 6.1.3, that was found between prototype version four and one as well as four and two. Both prototype versions one and two utilise an overlay menu to show the spin-offs. As described in the prototypes chapter, the overlay menu appears over the text of the tutorial and could thus be considered intrusive.
Some participants had difficulties locating the carousel in prototype six.	A further significant difference in the completion time was determined between prototype version four and version six. Qualitative feedback backs up this result as well. As described in the prototypes chapter, prototype version six utilises a carousel that appears within the step text at the bottom of the step. Six participants could not immediately locate the carousel when they clicked on the button <i>Show spin-offs</i> . This was mainly due to their scroll position that did not show the bottom of the step where the carousel was located. The six participants complained thus that the carousel could not be directly located.
Prototypes six and seven had no horizontal scroll bar.	A further point, that eight (57.14%) participants mentioned, was that they were at the beginning confused, whether they could scroll to the right. As figure 6.11 shows, we had a partially visible tile at the right as a signifier for being able to scroll horizontally. Four participants suggested nevertheless adding a horizontal scroll bar or an arrow at the right of the carousel as a signifier for the affordance for being able to scroll horizontally.
Step-based spin-offs were preferred by 78.57% of the participants.	In the short interview after completing the tasks, eleven (78.57%) of the participants said they preferred having the <i>Show Spin-offs</i> button directly located next to each step and not at the top of the project page. The reasons for this were better visibility of the button as well as fewer needed clicks to reach the target spin-off. As described in the prototypes chapter, <i>Show Spin-off</i> buttons located next to each step would only display the parameters that are relevant for the step, at which they are located. In contrast, the <i>Show Spin-</i>



Figure 6.11: The carousel in showing spin-off prototypes six and seven. Participants suggested adding a horizontal scroll bar as a signifier.

off button located at the top of the project page would show the parameters for all spin-offs that appear in the project.

A further reason, that was mentioned by four participants, was the improved locality. They said they expected tutorials to be broken down into steps, where each step mainly discusses one idea. Based on this, these participants indicated they preferred to see spin-offs of this one idea by clicking on the *Show Spin-offs* button, thus localising the button to the step. One participant mentioned that while reading a specific step in a project, they would be in a mental state of brainstorming alternatives to complete that step using the materials or tools that are on hand. According to that participant, having the spin-offs localised at each step would improve the makers' experience.

Breaking down tutorials into several manageable steps was also discussed by Huff [2021] in her guidelines for better maker project documentation. This supports the feedback that we received regarding the preference of discussing mainly one idea in each project step.

At an arithmetic mean of 4.43, prototype version five ranked as the third-lowest. Nevertheless, six (42.86%) participants said they would prefer using version five when making bigger changes to the project. They reasoned, that the wizard utilised by version five would facilitate the process of customising a project by consecutively selecting the spin-offs for all of the project parameters. An option to skip

Localising spin-offs could help makers better concentrate on each step.

Prototype five could be useful when manipulating multiple project parameters.

choosing a spin-off for some parameters was suggested. In that case, the originally used spin-off would be retained. Two participants suggested offering both versions four and five on maker platforms. Further research is needed to investigate whether offering both versions would lead to a better user experience.

We recommend implementing prototype four for showing spin-offs.

There is a lack of statistical evidence suggesting a significant difference between all prototype pairs. Yet as discussed, prototype version four was the best performing in terms of the arithmetic mean of all dependent variables. Qualitative feedback from the participants indicates their preference for version four as well. Thus, we make a recommendation for version four to be implemented.

6.2.2 Spin-off Creation Prototypes

The mean completion time of prototype one is better than two.

The arithmetic mean of completion time of prototype one ($M=89.85$) was better than prototype two ($M=104.77$). Because users do not have to pre-select the text in prototype version one compared to two, it is a logical consequence that the mean time is lower for version one.

Prototype version one ($M=1.38$) had a better mean ranking than version two ($M=1.62$) as well. Participants that were in favour of version one reasoned this for seeing it associated with less work, since they do not have to pre-select the text, to which the created spin-off is bound. The added benefit of having control over where the spin-off is bound was either ignored or not noticed by all participants that preferred version one.

Participants found prototype one requires less work, while two gives more control.

Three participants (23.08%) could not recognise the added benefit of prototype version two. The rest that preferred version one said it was sufficient to automatically detect where changes have been made and bind the newly created spin-off to the changed locations in the tutorial. Participants that preferred version two said being able to manually decide where the created spin-off is bound in the tutorial would be more empowering to the makers by giving them the freedom of choice.

The arithmetic mean of misclicks was lower in the case of prototype version two ($M=5$) in comparison to one ($M=5.77$). We could not collect any qualitative feedback that would help explain this difference, especially since prototype version two requires more clicks to be made. Using the extreme studentized deviate (ESD) method, we tested for the presence of significant outliers. We could find a significant outlier in the misclicks of prototype version one ($Z=3.28$, $p<0.05$). That was the case for a participant that tested version one before version two. That participant was confused by the window in figure 4.10, where the changed parameters are to be selected. The participant did not understand that two parameters were needed to be consecutively selected to proceed further. Thus, they resorted to closing and reopening the windows multiple times, resulting in many misclicks. By ignoring this participant's record, the mean of misclicks for version one ($M=2$) is lower than two ($M=4.08$). Using a paired sample t-test, we still could not identify a significant difference in *misclicks*, even after removing the significant outlier.

We identified a significant outlier in our *misclicks* data of a participant.

We could not identify a significant difference in any of the dependent variables between the spin-off creation prototypes. Yet based on the collected feedback from the participants as well as the lower arithmetic mean for version one in all the dependent variables (after removing the record with the significant outlier in misclicks), we make a recommendation for implementing prototype version one.

We recommend implementing prototype version one for spin-off creation.

When asked for improvement suggestions, multiple participants said they wished for a clearer placement for the *Publish* button after they had clicked on *Preview*. They said the button was hard to find. One participant suggested adding *Preview* as background text to the preview page to make sure users can recognise that their spin-off was not published yet. Three participants recommended changing the location of the *Publish* button to the right side of the tutorial page or the upper menu bar.

We received the suggestion of making it clearer on the preview page that the projects has not been published yet.

We also received a suggestion from two participants to make it possible to directly select multiple parameters at once in the pop-up shown in figure 4.10. Four participants suggested making it possible for makers to directly select

the changed parameters next to each step, instead of in the pop-up at figure 4.10.

6.2.3 Limitations

The tasks might have influenced the prototype rankings of the participants.

As discussed in chapter five, the study tasks entailed choosing the spin-offs, that fit specific criteria. Due to the simple nature of the tasks, this could have negatively affected the ranking of prototype version five. The benefit of using version five is being able to make changes to multiple parameters at once. Based on the given tasks, participants might have failed to recognise the added benefit for prototype version five, thus giving it a lower ranking.

Participants made only a few improvement suggestions.

After they have seen all the prototypes, the participants were asked to suggest other ways to show or create spin-offs. We received only a few suggestions, which we discussed earlier. Most participants said they had no other ideas than what they had seen. Because the participants were asked for suggestions directly after seeing all the prototypes, we suspect the participants might have been primed and, thus, could not think of new approaches.

Due to the online nature of the study, some measurement errors might have occurred.

The study took place online. Measurement errors might have occurred due to connection issues, such as lagging. While completing the tasks, some participants asked questions and gave feedback. To better assess the prototypes, we calculated in t only the raw time to complete the tasks. Thus, we subtracted the time the participants took to give feedback or ask questions. While completing the tasks though, participants were encouraged to share their thought process. This does not lead to time subtraction from t , because it is expected to happen simultaneously, while the participant is completing the tasks. Determining in advance whether the participant was sharing their thought process or giving feedback, as in suggesting design ideas, was difficult. Therefore, some measurement errors might have occurred while determining the exact duration of the feedback or the question, thus leading to errors in t .

Chapter 7

Implementation

According to our findings in chapter six, we implemented a website, that showcases the spin-offs feature. The implementation is based on prototype version four for showing spin-offs, and version one for creating spin-offs. The purpose of the implementation was to create a functional proof of concept of the spin-offs feature, as well as create a reference for future evaluation.

Based on our findings, we implemented a documentation website for makers.

The implementation is named *Magora* as a synergy between *Maker* and *Agora*. As described by Lindenlauf [2014], *Agora* was used as a word in ancient Greece to refer to something similar to a forum. Hence, *Magora* serves as a forum for project documentation in the maker community.

The project can be accessed on the following GitLab repository:

Magora: Implementation^a

^a<https://git.rwth-aachen.de/MichaelA/magora/-/tree/main/Implementation>

We used Vue.js¹ for implementing the frontend. For the backend, we used Node.js² as well as Express.js³ for build-

¹<https://vuejs.org/>(Accessed: 25.09.2021)

²<https://nodejs.org/>(Accessed: 25.09.2021)

³<https://expressjs.com/>(Accessed: 25.09.2021)

ing a RESTful API.

We used an SQL database in our implementation.

Based on the described nature of the spin-offs feature, the data would be structured with multiple relationships in our database. For that reason, and to minimise redundancy, we chose to use an SQL database. In our case, that was MySQL⁴.

The spin-off feature can be implemented using different technologies as well. Our above-mentioned choices were based on our perceived simplicity as well as familiarity with these technologies.

7.1 Use Case Scenarios

Appendix F shows a shortened version of the entity-relationship (ER) diagram of the database we implemented. The database scheme includes seven tables, two of which are bridge tables corresponding to the many-to-many relationships *Has* as well as *Influences*. We explain in the following three use case scenarios, how the user interactions will be processed in our database.

A project can contain multiple spin-offs.

Creating a new project As discussed, the spin-off feature differentiates between a project and a spin-off. A spin-off is a specific implementation of an abstract project. For example, a project titled *build a car* could have a spin-off about how to build an *Arduino-controlled red-coloured car*. Accordingly, users creating a new project have to enter a title for the general project idea as well as grant their own implementation of it a specific name. After that, the users enter the project steps. For each step, the user specifies the parameters that influence this step. In the case of the above-mentioned example, a parameter of a step talking about Arduino would be *microcontroller*. Its specific value in this spin-off would be *Arduino*. Figure 7.1 shows the screen, where the users enter the information required for creating a new project.

⁴<https://www.mysql.com/>(Accessed: 25.09.2021)

The title of the project along with the *userId* are saved in the *projects* table. The foreign key *userId* is saved to uniquely identify the user, who created the project. We then proceed with creating a spin-off based on the steps the user entered.

Create New Project

Figure 7.1: Screenshot from the implementation showing the screen where users can create a new project.

Creating a new spin-off An entry is first created in the table *spinoffs* that has the *projectId* and the *userId* as foreign keys. We then add each of the new steps to the *steps* table. In case a step was not changed in the newly created spin-off, we would not create it again. As appendix F shows, there is a many-to-many relationship between the entities *Spinoff* and *Step*. That corresponds to a bridge table called *spinoff_steps* in the database schema. We add the *stepId* of each step along with its order to that table. We also add the *spinoffId* as a foreign key to identify the spin-off, for which these steps are relevant. To be able to query the spin-offs of a specific step, we also add the *stepId* as well as the *spinoffId* of the original step, from which the step of the new spin-off

The bridge table *spinoff_steps* contains information regarding the order of each step in a given spin-off.

was derived. These are added as foreign key called *related-StepId* and *relatedSpinoffId* respectively.

Finally, we insert the names of the new parameters into the *parameters* table. As appendix F shows, there is a many-to-many relationship *Influences* between the entity *Parameter* and the relationship *Has*. This is implemented as a bridge table in our database schema. We insert the value of the corresponding parameter in a specific spin-off into that bridge table. Hence, this table references the bridge table *spinoff_steps* as well as the table *parameters*.

We query the spin-offs of a specific step by looking in two directions.

Showing spin-offs of a step To query the spin-offs of a specific step, we have to search in two directions. First, we look for the spin-offs, that were derived from that given step. The other direction is to look for the original spin-off, from which the given step was derived. We use the bridge table *spinoff_step* to query both directions.

Chapter 8

Summary and future work

8.1 Summary and contributions

In this thesis, we investigated ways of improving makers' experience on documentation platforms. After brainstorming several ideas, we decided to take a closer look at spin-offs. Adobe XD was used to develop seven prototypes that showcase different interaction possibilities of how makers can view spin-offs. Two prototypes were created to showcase how makers could create new spin-offs as well. Our goal from developing different prototypes was to triangulate the best approach to implement spin-offs.

We created prototypes for showing and creating spin-off.

We designed a user study that is composed of a task-oriented part followed by a short interview accompanied by a questionnaire. The study was used to evaluate the prototypes. The dependent variables were the time it took to complete the tasks for each participant, the number of misclicks, as well as the participants' ranking of each prototype. We could collect quantitative as well as qualitative data from the participants throughout the study.

We collected quantitative as well as qualitative data in our study.

The next step was to execute the study we designed. Accordingly, 14 participants took part in the study. We anal-

We could identify significant differences for some dependent variables in spin-off showing prototypes.

ysed the collected data. Based on the used prototype version, we could identify for spin-off showing prototypes the existence of a significant difference in the task completion time as well as in the rankings. Combined with the participants' feedback, we made a recommendation for prototype version four, which we proceeded to implement.

In the case of spin-off creation prototypes, we could not identify a significant difference in any of the dependent variables. Yet based on the data analysis using descriptive statistics as well as the qualitative feedback from the participants, we made a recommendation for prototype version one. We then created an implementation, that is based on this prototype version.

8.2 Future work

Further study might be needed on a high-fidelity prototype.

In the study conducted in this thesis, participants tested multiple medium-fidelity prototypes of the spin-off feature. We based our design implication on the quantitative data and the collected feedback. A further study on a high-fidelity prototype could be needed to ascertain our presented results. A possible candidate would be the implementation we proposed in chapter seven.

Implementing a mixture of version four and five in spin-off showing prototypes might have a positive effect.

We based our implementation of showing spin-offs on prototype version four. Multiple participants suggested in the study though, that a mixture of versions four and five could prove useful. We suggest further investigation of this suggestion and potentially extending the implementation we created.

The study we conducted in this thesis took place over Zoom. Due to connection issues, we could have experienced some measurement errors in the dependent variables. The tasks that we asked the participants to complete also had a simple nature. We suggest further investigation of the spin-off feature using tasks that are more complex in a non-remote study environment.

As discussed in the ideation chapter, many ideas could po-

tentially improve the makers' experience on documentation platforms. These ideas could be evaluated more thoroughly in future studies, especially the idea of *Tutorial Integration and Reusability*. We regard that idea as an extension of the spin-offs we investigated in this thesis.

A possible extension to the spin-offs feature would be to introduce multilevel parameters. In the case of steps that contain many parameters, these parameters could be grouped into more abstract ones. For example, the parameters *wheel rim colour*, *wheel diameter* and *wheel tire material* could be grouped under a new parameter called *wheel*. By grouping similar parameters, this could potentially facilitate the process of finding the right spin-off. Further investigation is needed to examine how makers would perceive this structure.

Extending spin-offs by making pre-existing projects reusable.

Grouping parameters could facilitate finding spin-offs.

Appendix A

Usability Questionnaire and Results

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. I think I understood what spin-off means.					
2. I found it easy to view spin-offs.					
3. I found it easy to create spin-offs.					
4. I would imagine that most people would learn to use spin-offs very quickly.					
5. I think being able to view or create spin-offs would motivate me to be a more active maker.					
6. I think using the spin-offs feature would improve my experience with DIY platforms.					
7. I found the spin-offs concept unnecessarily complex.					
8. I enjoyed using the spin-offs feature.					
9. I need to understand a lot about spin-offs before I can start using them.					
10. I think I would like to use the spin-offs feature frequently.					

Table A.1: Post-study questionnaire.

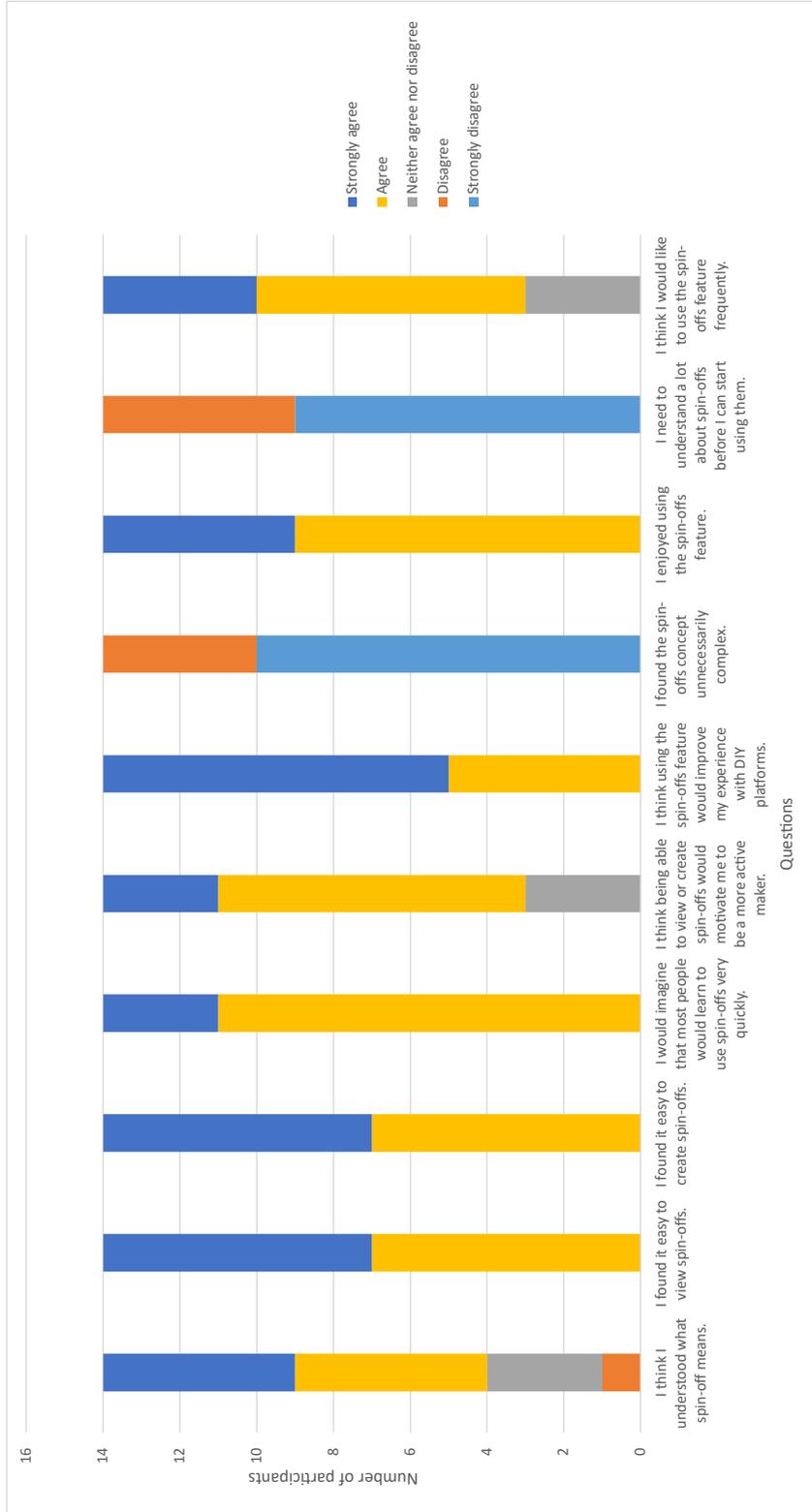


Figure A.1: Stacked bar diagram of participants' answers to the usability questionnaire.

Appendix B

Semi-Structured User Interview

Semi-Structured Interview

To collect further feedback, we conducted a semi-structured interview with the participants. We wanted to gain a better understanding of how they perceived the prototypes. We also wanted to ask for suggestions regarding other approaches on how to show or create spin-offs.

Questions

1. While viewing spin-offs, did you generally prefer the placement of the *Show Spin-offs* button next to each step or at the upper bar? Why?
2. Can you think of a different approach regarding how to show spin-offs? What would it be?
3. While creating spin-offs, do you prefer being able to bind it to a specific text or should it be rather bound to a step? Why?
4. Can you think of a different approach regarding how to create spin-offs? What would it be?

Appendix C

Background Information Questionnaire

Participant Background Questionnaire

Prototype Evaluation for Spin-off Viewing and Creation on DIY Platforms

1. How old are you? years old.
2. How many online DIY projects have you ever published?
3. Excluding the tutorials you published, how many DIY projects have you ever completed using online tutorials?
4. How many online DIY projects did you publish or complete within the **last two years**?

Appendix D

Informed Consent Forms

Informed Consent Form for not Recorded Sessions

Prototype Evaluation for Spin-off Viewing and Creation on DIY Platforms

Principal investigator: Michael Assad
 Bachelor's student
 RWTH Aachen University
 Mobile: +49 1522 4616519
 E-Mail: michael.assad@rwth-aachen.de

Purpose: The goal of this study is to understand how potential users perceive the concept of spin-offs and interact with the drafted prototypes. The results will be used to identify the strengths and weaknesses of the spin-offs as a concept as well as of the proposed prototype designs.

Procedure: This study will take place via Zoom as a scheduled audio call. Please make sure you have a working microphone as well as a recent Zoom version installed on your computer. You will be asked to perform a series of predefined tasks on multiple prototype versions. A link to the prototypes will be provided. You are expected to use the provided prototypes to find your way into completing the respective task. The session is intended to follow a think-aloud protocol, such that you tell us whatever comes to your mind as you are completing the tasks. Following this, you will be asked a series of questions in an interview setting followed by a questionnaire.

You are asked to share your screen as part of this study. Neither screen nor audio recordings of the Zoom session will be made. Written notes will be maintained for future evaluation (See "Confidentiality" below for further details).

Risks/Discomfort: There are no risks associated with participation in the study. You are free to take as many breaks as you feel necessary. Should you nevertheless during your participation become fatigued and/or feel discomfort at proceeding further, you may skip the task, discontinue the session, or withdraw your participation.

Confidentiality: All information collected will be used as part of my bachelor's thesis at the Media Computing Group at the RWTH Aachen University. You will be identified only through a random identification number. In no way should the data collected as part of this study be associated with your person or be used to identify any behavioral patterns that can be traced back to you. You are welcome to ask for the written notes to be shared with you at the end of the study. At your discretion, you may ask at any time for your data to be erased.

You will be asked to share your screen with us. You are free to pause or completely revoke the screen share at any point during the session.

If you agree to join this study, please sign your name below.

Addendums: Participation in this study is voluntary and not materially compensated. Participation in this study involves no cost to you. Please do not hesitate to contact me at the above-mentioned phone number or E-Mail address in case you have any further questions.

I have read and understood the information on this form.

I have had the information on this form explained to me.

Participant's Name

Participant's Signature

Date

Principal Investigator's Signature

Date

Informed Consent Form for Recorded Sessions

Prototype Evaluation for Spin-off Viewing and Creation on DIY Platforms

Principal investigator: Michael Assad
Bachelor's student
RWTH Aachen University
Mobile: +49 1522 4616519
E-Mail: michael.assad@rwth-aachen.de

Purpose: The goal of this study is to understand how potential users perceive the concept of spin-offs and interact with the drafted prototypes. The results will be used to identify the strengths and weaknesses of the spin-offs as a concept as well as of the proposed prototype designs.

Procedure: This study will take place via Zoom as a scheduled call. Please make sure you have a working microphone as well as a recent Zoom version installed on your computer. You will be asked to perform a series of predefined tasks on multiple prototype versions. A link to the prototypes will be provided. You are expected to use the provided prototypes to find your way into completing the respective task. The session is intended to follow a think-aloud protocol, such that you tell us whatever comes to your mind as you are completing the tasks. Following this, you will be asked a series of questions in an interview setting followed by a questionnaire.

You are asked to share your screen as part of this study. The Zoom session will be recorded. Written notes will be maintained for future evaluation (See "Confidentiality" below for further details).

Risks/Discomfort: There are no risks associated with participation in the study. You are free to take as many breaks as you feel necessary. Should you nevertheless during your participation become fatigued and/or feel discomfort at proceeding further, you may skip the task, discontinue the session, or withdraw your participation.

Confidentiality: All information collected will be used as part of my bachelor's thesis at the Media Computing Group at the RWTH Aachen University. You will be identified only through a random identification number. In no way should the data collected as part of this study be associated with your person or be used to identify any behavioral patterns that can be traced back to you. You are welcome to ask for the collected data to be shared with you at the end of the study. At your discretion, you may ask at any time for your data to be erased.

You will be asked to share your screen with us. You are free to pause or completely revoke the screen share at any point during the session.

If you agree to join this study, please sign your name below.

Addendums: Participation in this study is voluntary and not materially compensated. Participation in this study involves no cost to you. Please do not hesitate to contact me at the above-mentioned phone number or E-Mail address in case you have any further questions.

I have read and understood the information on this form.

I have had the information on this form explained to me.

Participant's Name

Participant's Signature

Date

Principal Investigator's Signature

Date

Appendix E

Balanced Latin Square

Prototype Nr. Participant ID	Showing Spin-offs							Creating Spin-offs	
1	4	2	7	6	5	3	1	2	1
2	6	1	7	4	3	5	2	1	2
3	7	5	6	2	3	1	4	2	1
4	2	1	5	3	4	7	6	1	2
5	3	6	5	2	7	4	1	2	1
6	5	4	3	1	7	6	2	1	2
7	1	2	3	5	6	7	4	2	1
8	3	7	1	4	6	2	5	1	2
9	4	5	1	3	2	6	7	2	1
10	2	4	6	7	1	3	5	1	2
11	6	3	2	5	1	4	7	2	1
12	5	7	2	6	4	1	3	1	2
13	1	6	4	7	2	5	3	2	1
14	7	3	4	1	5	2	6	1	2

Table E.1: Balanced Latin square used in the study. Order of the prototypes is represented by the table entries from left to right.

Appendix F

Entity-Relationship Diagram of the Implementation

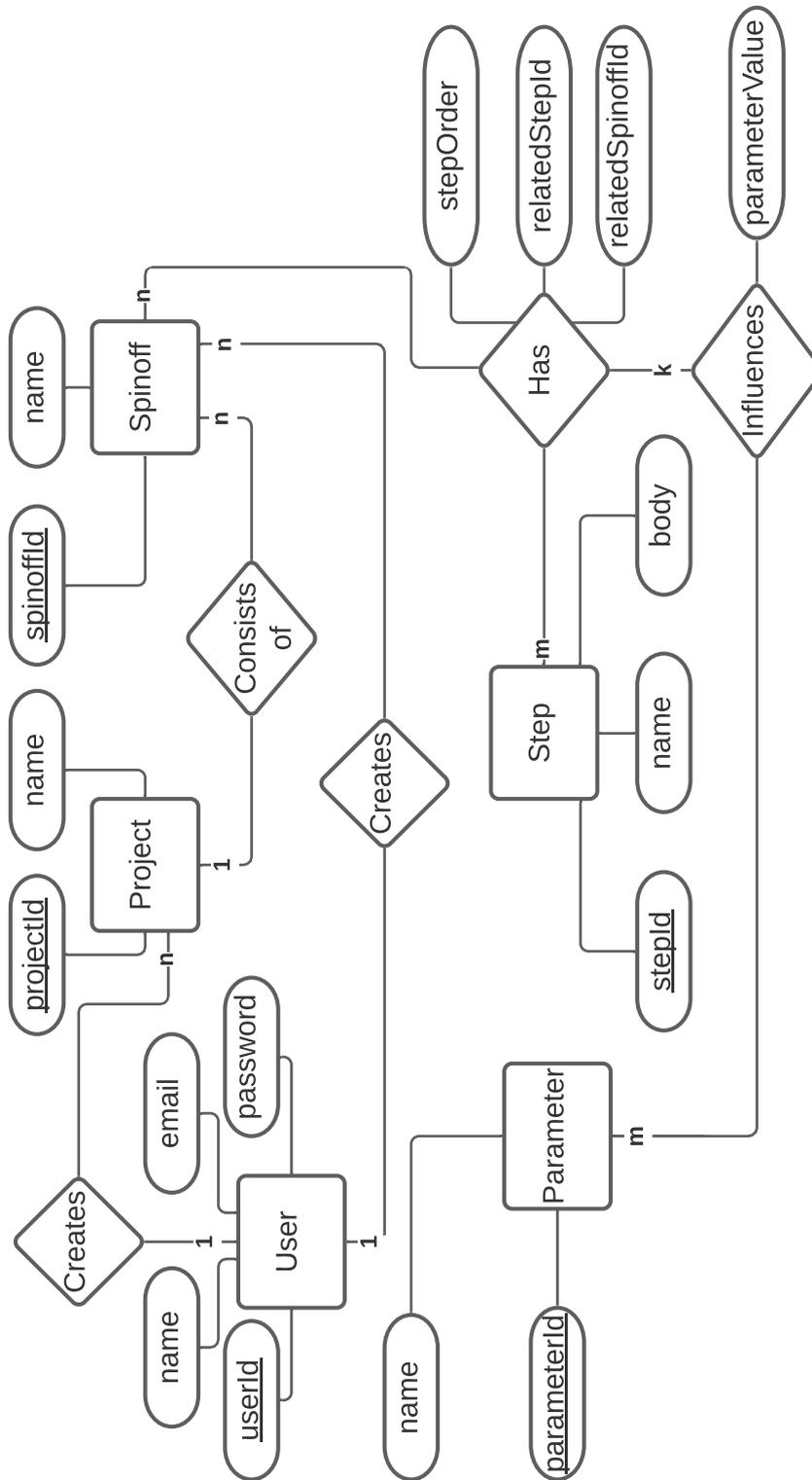


Figure F.1: Entity-relationship diagram of the database used for implementing spin-offs.

Appendix G

Adobe XD Prototypes: Image and text sources

Image and text sources

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