FAKULTÄT FÜR !NFORMATIK
Faculty of Informatics

snap science

Social Science Communication to Experience Research and Open Innovation

DIPLOMARBEIT

zur Erlangung des akademischen Grades

Diplom-Ingenieur

im Rahmen des Studiums

Medieninformatik

eingereicht von

Christoph Prinz, BSc
Matrikelnummer 1126371

an der Fakultät für Informatik
der Technischen Universität Wien

Betreuer: Ao.Univ.Prof. Dipl.-Ing. Dr.techn. Peter Purgathofer

Wien, 6. Juli 2016

Christoph Prinz	Peter Purgathofer

FAKULTÄT
FÜR !NFORMATIK
Faculty of Informatics

snap.science

Social Science Communication to Experience Research and Open Innovation

DIPLOMA THESIS

submitted in partial fulfillment of the requirements for the degree of

Diplom-Ingenieur

in

Media Informatics

by

Christoph Prinz, BSc
Registration Number 1126371

to the Faculty of Informatics

at the TU Wien

Advisor: Ao.Univ.Prof. Dipl.-Ing. Dr.techn. Peter Purgathofer

Vienna, 6th July, 2016

Christoph Prinz | Peter Purgathofer

Erklärung zur Verfassung der Arbeit

Christoph Prinz, BSc
Ottakringer Strasse 152/7+8, 1160 Wien

Hiermit erkläre ich, dass ich diese Arbeit selbständig verfasst habe, dass ich die verwendeten Quellen und Hilfsmittel vollständig angegeben habe und dass ich die Stellen der Arbeit – einschließlich Tabellen, Karten und Abbildungen –, die anderen Werken oder dem Internet im Wortlaut oder dem Sinn nach entnommen sind, auf jeden Fall unter Angabe der Quelle als Entlehnung kenntlich gemacht habe.

Wien, 6. Juli 2016

Christoph Prinz

Danksagung

Zu Beginn möchte ich mich an dieser Stelle bei allen bedanken, die mich während dieser Abschlussarbeit begleitet haben. Ein besonderer Dank gilt Ao.Univ.Prof. Dipl.-Ing. Dr.techn. Peter Purgathofer, der mich durch den gesamten Prozess der Diplomarbeit geleitet hat. Herzlichen Dank für die Ratschläge, Inspirationen und das Engagement, auf die ich stets zurückgreifen konnte und die mich immer tatkräftig unterstützt haben. Darüber hinaus möchte ich mich bei allen Test-BenutzerInnen und TeilnehmerInnen am Hackathon bedanken, die ihre Eindrücke und ihr Feedback mit mir geteilt haben. Nicht zuletzt gebührt mein Dank auch meinen Eltern und meinen FreundInnen, die mich während meiner gesamten Studienzeit immer unterstützt haben und mit ihren helfenden Händen stets an meiner Seite standen. Herzlichen Dank für alles.

Acknowledgements

I would like to give my acknowledgements to Ao.Univ.Prof. Dipl.-Ing. Dr.techn. Peter Purgathofer, who supervised me through the entire process of this thesis. Thank you very much for your advices, inputs and engagement through the learning process of my final work within my studies of Media Informatics. Furthermore, I would like to thank all my test users and participants in the hackathon, who have shared their thoughts and precious feedback to gain insights and findings. Last but not least, I thank my family and friends, who have accompanied and supported me during my entire studies and final thesis, both by always offering me a helpful advice and letting me focus on important issues. Thank you very much.

Kurzfassung

Das World Wide Web hat unsere Welt, wie wir sie tagtäglich sehen, verändert. Wir leben online und teilen unsere Gedanken mit allen anderen - immer und überall. Diese neue Art von Kommunikation hat auch einen beachtlichen Einfluss auf unsere *Wissenschaft*. Social Media und unser gesamtes Online-Verhalten verändern ständig unsere Wahrnehmung von Wissenschaft. Dabei muss sich ein eingefahrenes System immer wieder neuen Herausforderungen stellen. *Open Innovation* sowie *Citizen Science* sind zwei Ansätze, die sich in den letzten Jahren einer immer größeren Beliebtheit erfreuen.

Die folgende Arbeit greift diese neuen Herausforderungen auf und stellt sich diesen mit unterschiedlichen Ansätzen. Mit Hilfe eines *explorativen* Design-Prozesses werden vier Prototypen vorgestellt, die das Ziel verfolgen, unterschiedliche Lösungsansätze aus verschiedenen Perspektiven aufzuzeigen.

Ein erster Prototyp versucht die Lücke zwischen WissenschafterInnen und der breiten Öffentlichkeit zu schließen, indem er eine Plattform - inspiriert von *Crowdsourcing* - vorstellt. Im nächsten Schritt gewährt Prototyp 2 Einblicke in den wissenschaftlichen Alltag eines Forschers und erhöht so die Zugänglichkeit zur Forschung. Dabei ist es wichtig, den Usern entsprechende Anreize zu bieten. Im Rahmen eines *Hackathons* wurde dieser Prototyp evaluiert und getestet. Die Ergebnisse spiegeln sich in den nächsten Design-Iterationen wider. Prototyp 3 fokussiert sich auf die positive Belohnung von pro-aktiver Teilnahme im Prozess der Wissenschaftskommunikation.

All diese Konzepte bauen auf einem sehr breitgedehnten Rahmen auf. Aus diesem Grund fokussiert sich der letzte Prototyp auf ein spezifischeres Umfeld indem er eine Plattform zur Steigerung der Wissenschaftskommunikation im Österreichischen Schulsystem vorstellt. Diese Konkretisierung führt schließlich zu einem realisierbaren ersten Schritt, der die Wertschätzung von Wissenschaft erhöhen kann.

Die Arbeit setzt ihren Schwerpunkt auf den Design-Prozess als iterative Entwicklung. Technische Realisierungen werden nicht näher erläutert und diskutiert.

Abstract

The World Wide Web has changed the way we see the world. Today, we live online and instantly share our thoughts with each other - without limits. This kind of communication does have a significant impact on *science*. Online activities and social media sites change the perception of research work and trigger new challenges in a very well-established clientele. Open Innovation and Cititzen Science approaches are new public attitudes that have arisen over the last years.

The thesis tries to identify these new challenges and proposes different approaches to tackle them. Within an explorative design process, four different prototypes are developed. The goal of these concepts is to highlight the variety of possible solutions and different perspectives.

Starting with the idea of crowdsourcing and citizen science, a first prototype tries to close the gap between the public and scientific experts. The second prototype focuses on everyday insights to communicate what research work is about and shows the need to offer an appropriate incentive mechanism for user participation. A field test within a hackathon was held to qualitatively evaluate a prototype and to understand the real users' needs and desires. These ideas and findings get picked up in the third prototype that proposes an approach to reward pro-active engagement while diluting user roles.

All three attempts were built on a very broad setting. Therefore, prototype 4 tries to tackle the challenge of science communication with a more specific setting and introduces a platform for science communication within the Austrian general education system. Finally, a more concrete system design assigned to scholars' pre-scientific works allows to set a first step to push science communication to a new level.

The following thesis mainly focuses on the design process as an iterative development. Technical implementations will not be discussed in detail.

Contents

CHAPTER 1

Introduction

1.1 About this Thesis

Our knowledge is a precious common property. Research and scientific work represent a solid basis for innovation in all areas of expertise. Once a very small group of experts' privilege, nowadays science belongs to everyone. Digital age and the rise of social media platforms make us like, dislike, share and discuss all kinds of thoughts in public - more than ever. Science has not been spared from these public discussions. Therefore, new challenges about communicating the value and contribution of research have arisen and constantly arise.

In the last years, various approaches like *Open Science*, *Open Innovation* or *Citizien Science* showed a trend moving towards a new attitude: science does not only happen inside the borders of universities; everyone can do science. This thought lays the foundation for the following thesis that addresses the issues of a changing public understanding of science. An explorative design process tries to narrow the gap between researchers and non-scientists. The thesis investigates existing approaches, successful social media mechanisms from other areas and develops different prototype tools to support new ways of science communication.

1.2 Terminology

The following work will deal with various aspects of *Science Communication* and public understanding of science. Before starting a detailed discussion, a basic explanation should help to clarify the terminology. In 2003, Burns *et al*[BOS03] proposed a contemporary definition in this area of research that will be used throughout the thesis.

> *»SCIENCE COMMUNICATION (SciCom) may be defined as the use of appropriate skills, media, activities, and dialogue to produce one or more of the following personal responses to science (the vowel analogy)*

- ***A****wareness, including familiarity with new aspects of science*
- ***E****njoyment or other affective responses, e.g. appreciating science as entertainment or art*
- ***I****nterest, as evidenced by voluntary involvement with science or its communication*
- ***O****pinions, the forming, reforming, or confirming of science-related attitudes*
- ***U****nderstanding of science, its content, processes, and social factors*

Science communication may involve science practitioners, mediators, and other members of the general public, either peer-to-peer or between groups.«
(A definition by Burns *et al*, 2003 [BOS03])

When we talk about *the public*, we simply mean *every individual (e.g. scientists, decision-makers, interested people, non-experts, ...) in our society*. Science communication is a tool to connect *the public* with the world of research. The explorative design process within this work addresses the use of SciCom to make science available and accessible to everyone.

1.3 Structure of this Thesis

After a brief introduction and and explanation of important terminology as well as the work's aim, chapter 2 is concerned with fundamental motivations behind this work. A historical review will form the beginning of the thesis and will lead to a first explanation of new challenges in the field of science communication. Chapter 2 includes a general approach to science, its reputation metrics, and new attitudes like Open Innovation, Open Science and Citizen Science.

Chapter 3 of this thesis describes the methodological approach that has been chosen to investigate the issue. Starting with a general historical introduction of design processes, this chapter will explain the methodology that has been applied. An explorative design approach by Ron Wakkary tries to counter the *wicked problem*.

Having set up this motivational and methodological frame, a state of the art literature review will follow. This chapter 4 captures present research findings about science communication, general social media aspects, academic networks and will talk about incentive mechanisms to motivate user participation in online communities in general.

Chapter 5 of this thesis will then describe the practical part of this thesis including different prototype applications. Within the explorative design process, four prototypes (*inLab*, *snap.science*, *askScience* and *Science Streams*) have been iteratively developed. These design implementations all deal with various aspects of science communication. Different motivations, concepts, learnings and drawbacks will influence the four prototypes. These concepts have been implemented with different ranges of functionality.

The following chapter 6 focuses on the evaluation of *snap.science*, because this prototype has been implemented with highest degree of real implementation and brought up different aspects for further refinements and prototypes. User testing, group discussions and a field test at a hackathon (with great examples of alternative ways to communicate science) lead to a final discourse about science communication.

Chapter 7 summarises the process that has been applied, the prototypes that have been developed and the findings the thesis has gained. A critical discussion about science communication and a conclusion will then bring the thesis to an end.

1.4 Aim of the work

The aim of the work is to design an online tool for researchers and scientists to communicate their results and work in progress without the effort of long-term review processes and paper publishing efforts. Furthermore, this social platform allows scholars, undergraduate students and all other interested people to join science and to get in touch with research workflows. The website motivates researchers to share their insights on behalf of open innovation thoughts. Nevertheless, the platform focuses on not losing expertise roles in the bidirectional conversation about science.

To come up with this kind of online platform, successful social media strategies and modern social exchange paradigms are analysed and applied to science communication. As Cami Ryan [Rya15] states, science is very complex, per se, but people are not interested in hearing about science in the way science wants to present itself. Therefore, science communication needs to focus on metaphors and stories to get the attention of the audience - as examples from a creative hackathon (see *6.1 Field testing: Hackathon*) show. The science communication web application should use a storytelling approach and offer a toolkit to support this.

The attempt to design and develop a new online platform does not mean to simply find a first solution to the problem. An iterative design process with various prototypes helps to approach science communication and learn from different concepts. The aim of this thesis is not to fully implement one platform with all its details and specifications. The following work investigates and discusses ideas and concepts to narrow the gap between science and public communication. There is no focus on technical implementations; rather the design process and decisions will be discussed with priority.

All prototypes and concepts should be beneficial to society. Commersialising thoughts or underlying business models will not appear at any stage of the ideas.

CHAPTER 2

Motivation

2.1 A Historical Introduction and New Challenges

The question of how much publicity science really needs has been an open dispute since the early days of research and goes back to fundamental papers. Prussian Nicolaus Copernicus (1473 - 1543), who devoted himself to mathematics and astronomy, published a revolutionary concept of the world that we now see as the beginning of modern astronomy: the *heliocentrism*. In his most important work called *»De revolutionibus orbium coelestium«* [Cop95] (English: *On the Revolutions of the Celestial Spheres*) he demonstrated the immanent attitude towards science and the public back then: He opened his new theory with the following line: *»Let no one untrained in geometry enter here«* [SW08]. At this time, when scientists worked on behalf of royals and monasteries, science has been exclusively reserved to a very limited circle of well-educated experts. The endeavour of public understanding did not exist.

This idea of protecting scientific findings first became softened during the Age of Enlightenment (18th century) when reason has been attributed to everybody and people have started to use their individual intellect. Mathematicians and physicists have been the driving force to push science and coined the term *»Scientific Revolution«* [Han85]. Furthermore, Johannes Gutenberg's (1398-1468) invention of the printing press and the following industrialisation supported the ongoing change of public access to knowledge and science.

Today, the *Digital Revolution* has again changed and influenced the way we communicate science. New opportunities and challenges constantly arise with the introduction of new online media. In digital ages, the way we pursue science has been revolutionised. The creation, transfer and storage of knowledge changed with the introduction of the World Wide Web. However, the objective of science still remains the same [LK14].

Learning from new online communication models that have evolved over the last years and constantly try to obtain maximum reach, this thesis aims to combine a broad social media reach with science communication. Present science is challenged by a shift from simply broadcasting information to a *convergence* model where everyone can contribute - as Luers and Kroodsma [LK14] say - *«without diluting expertise»*.

2.2 Do you know science?

Science is everywhere and it is becoming more and more of a national and international political interest. Many people blame the educational system for not doing a good job when people fail at simple scientific tests [Wil12]. Even before the advent of social media platforms and online communication a mistrust towards the scientific enterprise has been recognised [Soc85]. Scientists have been encouraged to learn to communicate with the public. Nevertheless, in 2011, an American study by Research!America [Res10] revealed a really alarming situation: 63 percent of people were not able to name any living scientist - and they did not even try to. Therefore, Donald Kennedy *et al* encourage scientists to take use of good public relations practices and to *sell* their science:

> *»The scientific community needs to understand what ethical practitioners of public relations have long known: trust is not about information; it's about dialogue and transparency. [KO10] «*

Regarding to Kennedy *et al* [KO10] one has to understand the art of public relations to understand how science communication works. It is about creating significant realationships with the public audience to communicate scientific work.

2.3 A scientist's every day

Oliver Smithies, a geneticist and 2007 Nobel Laureate in Physiology and Medicine, emphasises an immanent attitude towards traditional science publications versus new media communications: *»It isn't science until it is published.«*. Today, this maxim still drives the majority of scientists to publish their work in traditional journals within a long-lasting paper review workflow [LK14].

Christie Wilcox, a scientist, science writer and social media specialist from the University of Hawaii talks about the scientific everyday world: Successful scientists spend their day with researching and finding the latest knowledge acquisitions with the goal of publishing in top-level specialist journals. Although this is a good way to establish reputation within the small area of experts, the cutting-edge findings won't be communicated to non-scientists. Reality shows that papers are *»locked behind paywalls «*. Even if they are freely accessible, there is still the barrier of commonly understandable terminology, so Wilcox [Wil12]. Sending out a press release will not be the key to solve the problem: *»It is the scientist's job to share his or her research with the broader community.«*

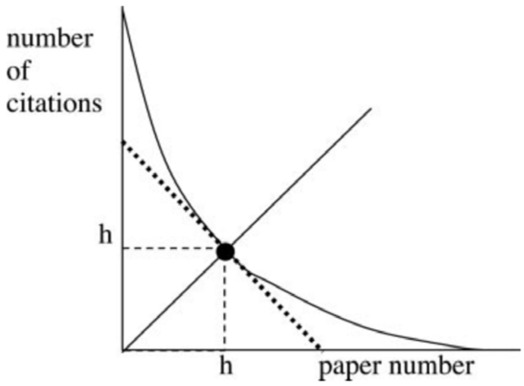

Figure 2.1: Graph shows number of citations compared with the number of papers. Image source: [Hir05]

2.4 The h-index

The impact of science in general is obvious and not questionable. However, in 2005, J. E. Hirsch [Hir05] tried to find a method to measure the individual researcher's input and relevance. He proposed the so-called *h-index*. It should help to quantify scientific output and reputation. The index is based on the amount of citations of scientific publications.

A scientist's *h*-index is defined by Hirsch as the number of publications that have been cited by others at least *h*-times. To calculate the individual's h-index, one has to order all publications by the number of citations. Next, starting at the most cited publication, one has to count through the ordered list until the publication on position x has less citations than x. The graph in figure 2.1 shows this correspondence between number of publications and number of citations that defines the h-index.

This simple metric to quantify the impact of science receives great criticism. Michael Wendl talks about *context* that is very essential [Wen07]: *»Many citations are used simply to flesh out a paper's introduction, having no real significance to the work.«* In addition, negative citations also positively affect the h-index. Studies also show that the h-index is not sufficient when different fields of science are compared [ACHVH09]. Furthermore, influencing parameters like the length of the scientific career or age make the index not meaningful. This may also lead to a researcher's change of his/her publishing behaviour resulting in intentional self-citations and publications with the sole purpose of pushing their h-index [Wen07] [ACHVH09].

To overcome these drawbacks, various approaches that try to refine the h-index and counter the critical arguments arose [AHK08] [Egg06] [Zha09].

2.5 Altmetrics

The workflow of research is underlying a constant change and is seriously influenced by social media at any stage [NR11]. Therefore, in 2010, a new movement in terms of measuring scientific impact arose: *altmetrics* [PTGN10]. The altmetrics' manifesto follows a clear motivation:

»No one can read everything.« (Altmetrics Manifesto [PTGN10])

This sentence shows that there are other metrics to filter important literature out of an infinite offer of publications. Traditional metrics to measure scientific impact like the h-index are really slow and only include traditional science publications. It happens to last years to get the first citation of a published work. Today, science communication and publication lives online. Scientists share their insights on the world wide web with all its opportunities. Twitter, Wikipedia, Web blogs, and all other social media channels are used to spread the work. Altmetrics collect all this information to create an instant and alternative index. A study by Hamed Alhoori and Richard Furuta [AF14] showed that a newly proposed science index that was not based on traditional citations but rather collected data from several social media platforms significantly correlated with traditional metrics based on citations.

This idea of creating an alternativ metric for science contribution will be picked up in a later prototype during the explorative design process (see *5.3 Prototype 3: askScience*).

2.6 Open Innovation & Open Science

To get the meaning of the term *open innovation*, one has to understand what *innovation* per se means: Following a definition by businessdictionary.com, innovation represents an applied idea that provides a value to someone:

> *»The process of translating an idea or invention into a good or service that creates value or for which customers will pay. To be called an innovation, an idea must be replicable at an economical cost and must satisfy a specific need. Innovation involves deliberate application of information, imagination and initiative in deriving greater or different values from resources, and includes all processes by which new ideas are generated and converted into useful products. In business, innovation often results when ideas are applied by the company in order to further satisfy the needs and expectations of the customers.«*
> *(BusinessDictionary.com [1])*

In other words, this means that companies or institutions will only create innovation if they manage to turn their ideas and inventions into an applied service or product that satisfies somebody's need. This appliance of ideas used to be a very internal and protected process.

[1] Definition of *Innovation* by businessdictionary.com. http://www.businessdictionary.com/definition/innovation.html, accessed on 2016-05-02

Henry Chesbrough even describes it in a more simple way, saying: *»[...] innovation means invention implemented and taken to market.«* [Che06].

This internal innovation's approach has been adopted in recent years. In 2003, Henry Chesbrough, who co-founded the Open Innovation Community[2], introduced the term *Open Innovation* as the following:

> *»Open Innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology. Open Innovation combines internal and external ideas into architectures and systems whose requirements are defined by a business model.« (Henry Chesbrough, 2003, [Che03])*

This philosophy can also be applied to a scientific context: *Open Science* opens research and scientific processes, which are likely to be publicly funded, to everyone and includes the whole process starting with a first idea to the final publication. The goal is to enable access to scientific and common knowledge, ongoing debates and research projects to the public that allows reproduction and comparison of research work. [ope16]

In 2011, Kraker *et al* [KLR$^+$11] introduced four principles that define Open Science at a more detailed level:

- **Open Access** allowing the public to access scientific work.
- **Open Data** enabling access to the data generated to everyone.
- **Open Methodology** making research workflows transparent including relevant documentation.
- **Open Source** ensures to use open and own technology. Also includes public access to scientific prototypes.

In addition, Kraker *et al* also talk about some issues this open philosophy brings along: There are several drawbacks that have to be considered when scientific data is shared. First, legal problems have to be addressed with defined guidelines, formats and licences. However, social issues including time-consuming documentation, data theft without citation, copyright issues, publication rights and research competition do have a real impact [Sto09].

To help with all these issues, a European commission called *FOSTER* [3] provides a training platform about Open Science. They introduced a taxonomy to help understand and apply this approach in detail [PKCP15].

[2] See www.openinnovationcommunity.net
[3] Facilitate Open Science Training for European Research, https://www.fosteropenscience.eu

2.7 Citizen Science

Amateurs and hobbyists have been researching the earth since the first records of history [BSP+14]. Nevertheless, the term *citizen science* came into being in the middle of the 1990s, as two approaches appeared in 1995: Alan Irwin influenced the idea to *democratize science* [Irw95]. A more influential definition has been made by the Cornell Lab of Ornithology, a bird research unit at Cornell University in Ithaca, New York [Cor16]. They talked about the participation of non-scientists in the process of research, as the public got included in data acquisition methods, and encouraged volunteers to collect data about birds [oO96].

Recent work by Rick Bonney *et al* examines the impact of citizen science and science participation on the public image of science [BPBE16]: As a result, present challenges in the field of public awareness of science have been identified. They show that many citizen science projects are aiming at refining the public attitude towards science. However, there are few projects that are really designed to achieve this goal. In addition, the evaluation and measurement of outcomes still need improvement. Another issue they discuss is the motivation and creation of new participants. Most of the projects tend to address the upper educational level of society. If citizen science tries to follow Alan Irwin's idea it should include all levels of society. Finally, Bonney *et al* state that it is all about understanding *how* participants learn (while they are part of a citizen science project) to find out *what* their personal learning outcome is.

A big increase in citizen science projects all around the world shows that this field of science gets more and more popular. Technological transformations, mobile applications and the World Wide Web are key contributors to this development. Results and outcomes demonstrate the scientific contribution. Nevertheless, publications and research studies based on publicly collected data struggle to find scientific esteem. Low quality of data and a lack of data collection training are the arguments against citizen science [BSP+14].

Despite all critical voices, citizen science represents an approach to include the public in a scientific context. It helps to make research processes accessible and maybe understandable to everyone. This idea coincides with the motivation of this thesis and will be seized again in a first prototype concept (See 5.1 Prototype 1: inLab).

CHAPTER 3

Approach & Methodology

After a literature review and an analysis of existing approaches in the field of science communication, various prototype applications are developed. Technologies like Python, HTML5, CCS3, Javascript and the Django framework[1] are used. Within a science communication hackathon on behalf of the *Austrian Federal Ministry of Science, Research and Economy*[2] a prototype is presented to and tested by first users, allowing instant feedback (thinking aloud). A group discussion and interviews further define and shape the prototype in an iterative process. This evaluation results in a redesigned prototype implementation focusing on user experience and storytelling.

3.1 Brief History of Design Processes

Going back to the early beginnings and origins of *design* or *design processes* will lead to the Renaissance. Referring to Richard Buchanan [Buc09], Philosophers like Galileo Galilei, Pico della Mirandola and Francis Bacon are considered to have been the first design pioneers.

Before one can follow the path of development the term *design* has gone over the years, we have to understand what exactly is meant by *design*. In 1990, John S. Gero [Ger90] tried to answer this question with his following statement : *"Designers are change agents in society."* He proposed the goals that design always tries to improve and refine human conditions. This is realised with the application of physical change. Gero also mentioned that design has been recognised even more than four thousand years BC. The King of Babylon - Hammurabi - introduced a design law that proves the recognition of design back then:

> *»If a designer-builder has designed-built a home for a man and his work is not good, and if the house he has designed-built falls in and kills the householder,*

[1] http://djangoproject.com
[2] Bundesministerium fuer Wissenschaft, Forschung und Wirtschaft, http://www.bmwfw.gv.at

> *that designer-builder shall be slain.«*
> (quoted by Gero, 1990 [Ger90])

N. Cross - author of the book *Design Methodology and Relationships with Sciences* summarises the origins of design methods[dVCG93]: The emergence of design as a scientific field first came up after World War II. In the 1960s, this new design movement laid its fundamentals within a series of design conferences starting with *The Conference on Design Methods* in London in 1962. Conferences all over the world followed.

In the emerging discourse about design and design research, Christopher Alexander took an important role: He questioned the practices of the genius and proposed a more methodological approach [Ale64]. Alexander's critique aimed at the individual's impact on the design object. This attitude shows and emphasises *the first generation* - coined by Rittel [RW73] - that design processes can be rationally defined back in the 1960s. With the beginning of the 1970s, the *second generation* of design pioneers arose, where Herbert Simon comes into play. Simon introduced the term *satisfiction* and first talked about evaluating and verifying a design solution [dVCG93]. In addition, Simon took the process of designing to a more abstract level of problem solving when he said:

> *»Everyone designs who devises courses of action aimed at changing existing situations into preferred ones.«*
> (Herbert Simon, 1969 [Sim96])

The discussion about design process got rattled when Rittel & Webber [RW73] first introduced their definition of *Wicked Problems* in 1973. Their new approach established the fundamentals for many new design thinking methods and will be discussed in the following section *3.2 Design Approach of this Thesis*.

In the 1980s, design methods in the field of engineering developed. Several *International Conferences on Engineering Design (ICED)* and the endeavour of the *Verein Deutscher Ingenieure (VDI)* were the driving force, especially in European countries. The next significant step in the development of design theories was built on the introduction of new design journals like *Design Studies* or the *Journal of Engineering Design* [dVCG93].

3.2 Design Approach of this Thesis

Science communication is a subject with loads of different influences as science per se is very diverse. Therefore, many complex problems, different opinions, barriers and even more potential solutions are abound. But we cannot solve the problem by simply applying conventional design strategies. In 1973, Rittel and Webber [RW73] first defined this kind of problems as *wicked problems*, that can be tackled with the help of Ron Wakkary's concept, proposed in 2003. This design methodology will be used in this thesis.

3.2.1 Wicked Problems

Rittel and Webber [RW73] distinguish between *tame* and *wicked* problems. Tame problems do have a definite formulation of the problem and offer all information needed to solve them. On the contrary, it is not possible to formulate wicked problems in all details, because the details needed depend on the approach of solving them. In other words: Solving a wicked problem would be the same as exhaustively formulating the problem. Following Rittel and Webber, wicked problems do not have a *stopping rule*. The problem solver does not know when *the* solution has been found. Furthermore, there are no *true* or *false* solutions to these kind of problems. The only thing we can tell about them is whether they are *good* or *bad*. Mechanisms of verifying solutions do not exist. [RW73].

All these characteristics of wicked problems apply to the underlying research question of this thesis. Science communication is a complex field where it is impossible to define a starting and an end point. Designing a platform to *revolutionise* scientific communication would be a solution to the problem. However, this is not possible. In order to tackle this wicked problem we chose an *explorative design approach*. This wicked problem is the reason why this thesis can not provide one simple and final solution.

3.2.2 Explorative Design Approach by Ron Wakkary

In line with Ron Wakkary [Wak03], Umerto Eco stated the answer to how to tackle wicked problems:

> *»The important thing is to make a start. [Umberto Eco 1997] «*

In 2003, Ron Wakkary seizes two concepts - *(1) framing the problem* and *(2) designing »in-the-world«* - and proposes a new design approach [Wak03]. This explorative design approach is considered to tackle wicked problems. *Iterations* are the key aspects of this design method. The designer can repeat every single step throughout the whole design process and can go back to any arbitrary point of progress. Another possibility of an iterative and explorative method is *rushing* through the entire steps of the design process to get *real-world* user feedback from a prototype. Therefore, designers need to be flexible with the reaction if something goes wrong. This concept will be demonstrated with *5.2 Prototype 2: snap.science* in the context of field testing at a hackathon (see *6.1 Field testing: Hackathon*). It is all about learning from iterations to *get it right*, so Ron Wakkary [Wak03].

As this thesis has a very explorative character, the proposed design method by Ron Wakkary has been chosen. Conceptual drafts, prototypes and *"in-the-world"* field tests will demonstrate these processesses of tackling a wicked problem.

3.2.3 Sketching

The famous biochemist and Nobel laureate Linus Carl Pauling (who died in 1994) said:

> *»The way to get good ideas is to get lots of ideas, and throw the bad ones away. [Linus Pauling [Cri92]] «*

Figure 3.1: Digital sketching on a tablet with a smart tablet pen.

The quote by Pauling highlights what designing and developing an idea means. There are numerous ways of ideation, but it is the designer's task to combine, filter and skip these ideas to create something valuable. This approach also encouraged Roberts *et al* to summarise the benefits of design techniques like sketching and prototyping: To generate various ideas, one has to find an instant way to record thoughts and concepts. In combination with low-fidelity mockups and prototyping, sketching can help to prove a concept or refine ideas to become a real product [RHR16] .

Bill Buxton [Bux07] focuses on sketching as the most essential part throughout the whole design process. The *sketching phase* is an implicit but very important step in almost every design scheme [Mit15]. In addition, Buxton shows that sketches offer a way to explore possible solutions and to refine user experience at a very early stage of the design process. An iterative process may develop the idea from various experimental drafts to the optimal solution. It is about sketching and learning from it, so Buxton [Bux07].

Sketching is not about drawing beautiful pictures [Bux07] [RHR16]. It is about capturing thoughts and presenting them to others in a collaborative work setting. Figure 3.2 shows an example of a sketch that has been used to express a conceptual idea during the design

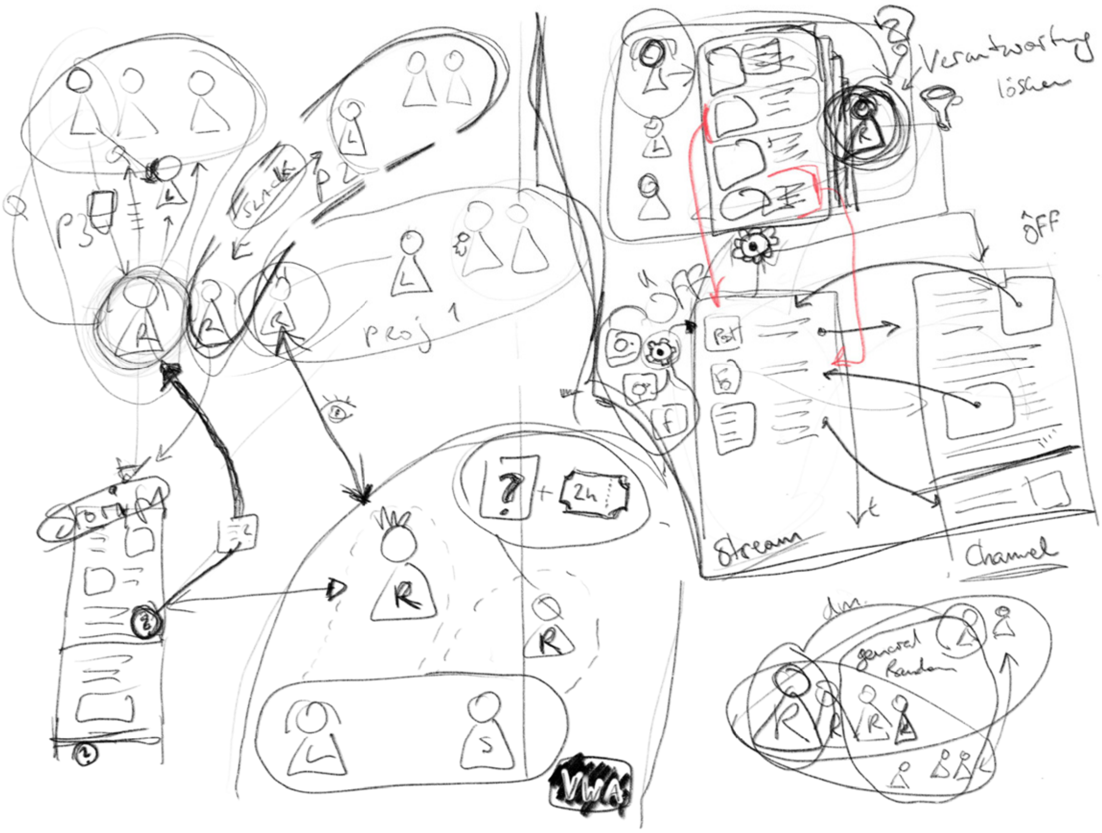

Figure 3.2: A sketch that has evolved during a design session while developing a new prototype concept.

process of this thesis.

Sketching has been applied at any stage of the design process of this thesis. Simple pen & paper drafts as well as digital sketching tools (see Figure 3.1) have been used to discuss thoughts, express ideas or argue complex design decisions. These sketches have evolved over the entire design process. The following chapters will include some of the sketches that demonstrate the low-fidelity representations of thoughts during the design process.

3.2.4 Prototyping

»A *Prototype* is a working model built to develop and test design ideas«, so Walker *et al* [WTL02]. It is used to prove a concept, research interaction techniques, aesthetics and user experience. Usability engineers use prototypes to observe how potential target groups perform and act with the system. Generally, there are two types: *low-fidelity* and *high-fidelity* prototypes. While hi-fi prototypes come very close to (and are often built with the same methods than the) final product , lo-fi prototypes only represent a conceptual model without full functionality [WTL02].

Since the 1990s, *low-fidelity prototypes* have become a popular design method. In line with Virzi *et al*, lo-fi prototypes help to efficiently understand the design space and show predictive user experience issues. Furthermore, they involve the user participation at a very early stage and enable access to different approaches and solutions. They even *»provoke innovation«*, so Virzi *et al* [VSK96].

Lo-fi prototypes are less time-consuming and not expensive, compared to complex high-fidelity protoypes [WTL02]. Comparing the fidelity of the prototypes that have been built in within this thesis, Prototype 1 and 2 have the highest degree of fidelity (with an implemented online platform), while Prototype 3 only represents a conceptual mockup design. Prototype 4 includes a HTML mockup for prototype testing. See Chapter *5 Design Process* for detailed prototypes.

3.3 Evaluation

Evaluation of this thesis is based on *qualitative research* concepts and methodologies as Keith F. Punch [Pun05] defines:

> *»Quantitative research is empirical research where the data are in the form of numbers. Qualitative research is empirical research where the data are not in the form of numbers.«*

In social research, Philipp Mayring [May02] has made fundamental contribution to the idea of *qualitative thinking* and has coined the five principles of qualitative research:

- Qualitative Research is about humanity; people are the *subjects*.
- A *description* of the subject area has to be made in advance.
- The object of inquery is not obvious. It has to be developed with *interpretation*.
- Humanistic subjects have to be researched within their *natural settings*.
- *Generalisation of findings* has to be justified gradually. It does not come automatically.

Mayring's basic idea of qualitative research will be picked up throughout the entire design process of this thesis. Chapter *6 Evaluation* will show a more detailed account regarding this issue.

CHAPTER 4

State of the Art

4.1 Science Communication

Science communication faces a lot of novel challenges with the introduction of the Internet and social media platforms. Many scientists and researchers have a very limited approach to communicate with the public. It is very likely that research results and insights are only published in a simple press release by the institutions' public relation department, as Liang *et al* [LSY+14] summarise. In 2014, they conducted a study discussing the research question about scientific impact in new online mass media and analysed scientists' public communication behaviours. The results show, without limitations, that a scientist's online participation (e.g. active Twitter account) does have a positive impact on traditional bibliographic metrics like the h-index (proposed by Hirsch [Hir09]).

Another case study in the field of science communication was carried out by Jason Yip *et al* [YAC+14] in 2014: They introduced a social media tool to *»scientize the daily experiences«* of children learning about science and emphasised that social media platforms *»can offer promising ways to afford learning behaviours and experiences for children«*. For example, so-called micro-contributions (sharing ideas, insights, comments, etc.) decrease the barriers to enter participation [YAC+14][p. 162].

Holly M. Bik and Miriam C. Goldstein [BG13] also see the urgent need for revolutionising science communication when they say: *»Online social media tools can be some of the most rewarding and informative resources for scientists - IF you know how to use them.«* They counter the lack of scientists' online awareness with social media guidelines and an introduction for scientists.

Lisa C. Kaczmarczyk [Kac15] talks about alternative methods, like improvisational theater, to spread the scientific word. These kinds of alternative methods have been applied in the hackathon, that has also been used to evaluate a prototype of this thesis. To see the results of alternative science communication see *6.1.4 Alternative ways to communicate science*.

All modern approaches of science communication include storytelling as a key concept in their strategy. Cami Ryan [Rya15] underlines this need for attracting the audience's attention and refers to Paul Zak's [Zak15] work: A story is successful, if it draws the reader in. Therefore, a successful science communicator has to find metaphors that create images in the reader's brain. These concepts have to be considered when communicating complex science topics on a web platform to an open and broad audience.

4.2 Social Networks - Learning from Success Stories

There are countless social network platforms online. The following section will have a look at different networks and identify their strengths.

4.2.1 Facebook - Virtual vs. Real Communication

Facebook is one of the biggest and most successful social network sites out in the World Wide Web. Founded in 2004, Facebook now counts over 1.09 billion daily active users (March 2016) [Fac16]. The company's mission is *»to give people the power to share and make the world more open and connected. People use Facebook to stay connected with friends and family, to discover what's going on in the world, and to share and express what matters to them. [Fac16]«*. Although this company slogan may be found in various social communities, Facebook's numbers prove their success.

Despite critics always talking about virtual friends and their negative aspects, Davies *et al* [DMB16] summarise what Arnaboldi *et al* [AGP13] also found out: Facebook is an extension to real-life and offline connections and friendships. Of course, there is a great opportunity to meet new people, but Facebook users tend to mainly interact with a well-known network, so Davies *et al* who tried to approach the question why people use this social network site. Based on Nadkarni's and Hofmann's [NH12] research, there are two reasons why people use Mark Zuckerberg's platform every day:

- People want to *belong to* specific social groupings and networks
- Social networks are used to *construct personal identity* and *self-presentation*.

However, we should not see Facebook as a replacement for interpersonal communication. It is not about substituting offline communication, as investigations show [DMB16]. It is very important to think of this finding when we try to learn from Facebook mechanisms and apply them in different settings. The prototypes that have been developed during the design process will - of course - make use of social network practices and techniques that also can be found on Facebook (e.g. the like button). There is a huge stock of research and literature about Facebook that the present thesis is aware of, but it is not the motivation of the thesis to discuss these mechanisms. At this point, the input and finding not to try to substitute real-life connections has affected the design process.

4.2.2 Stack Exchange - The Connection of Questions & Answers

Stack Exchange[1] is an online network consisting of over 150 different Q&A communities with millions of questions each, as figure 4.1 shows. Besides *Stack Overflow*[2] that represents the biggest community for software programming, there are various topics like photography, mathematics, travel or French Language. The StackExchange network connects questions and expert answers in every area of expertise. By 2015, 3.7 million questions have been asked and 4.6 million answers have been submitted. A simple up- and down-voting mechanism of answers helps the 3.9 billion unique users to find the best solution to common problems [Sta16].

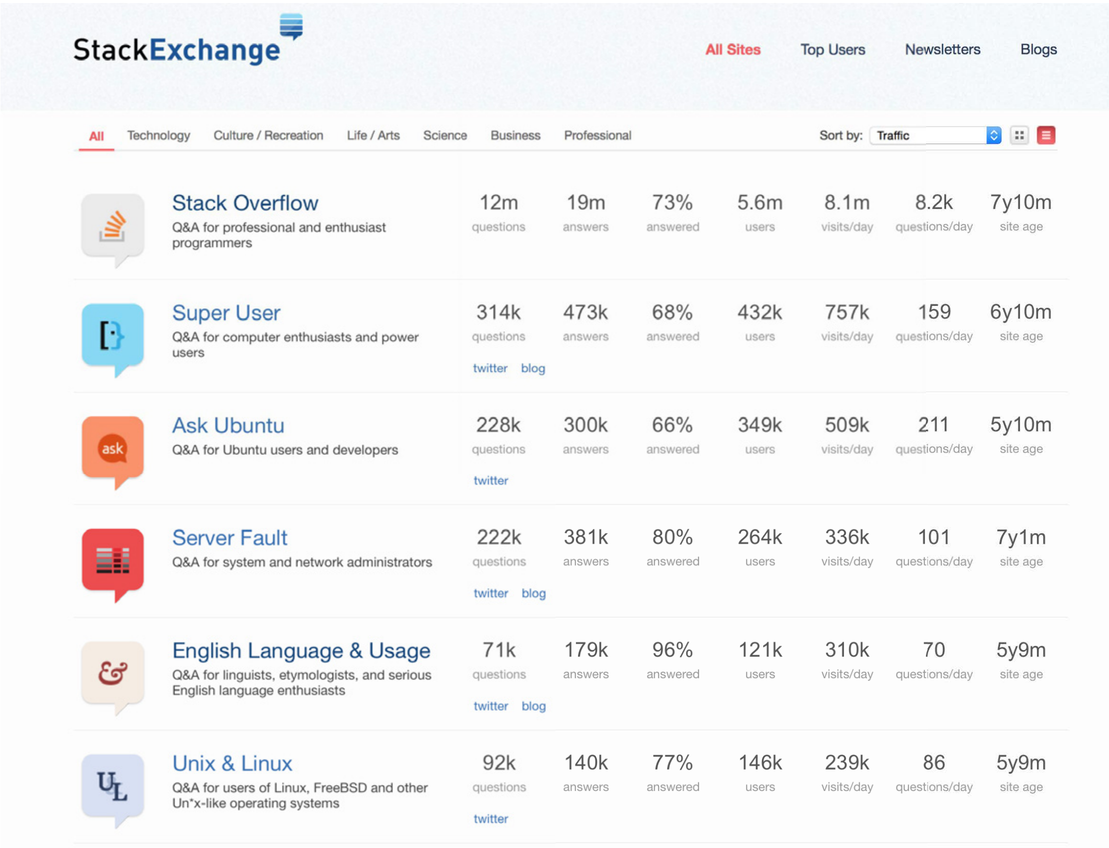

Figure 4.1: Top Q&A sites within the StackExchange network.

Although StackExchange sites are social network platforms, Vice President of Engineering David Fullerton thinks critically about that: *»What separates us from a traditional social network is our focus on Q&A. We're not interested in discussion [...] We actually think communities work best when they work together to solve problems, not just come together to*

[1] http://www.stackexchange.com
[2] http://www.stackoverflow.com

chat. [BBS13]«. Referring to him, the content of the question is most important. Personal information about the author or background information are secondary.

Stack Overflow or all other Q&A sites within the Stack Exchange network show that self-presentation, as Facebook demonstrates (see *4.2.1 Facebook - Virtual vs. Real Communication*), does not have to be the driving force for all social communities. Finding an expert's answer to an individual problem is a common motivation to make use of or join social network platforms. The connection of *questions* and *answers* will be captured in a later prototype within this thesis.

4.3 Academic Social Networks

Recent studies try to examine and understand the exchange of information in an academic context [JDHL15] [TK15] [TK14] [JHJ15]. To distinguish social network platforms with a high focus on a scientific audience from a more general social network site, Jeng *et al* uses the term *Academic Social Networking Sites (ASNS)* [JDHL15]. The following work will refer to this terminology. ASNSs are used to share and exchange scholarly information, also considered to be a tool for *information flow* or *knowledge transfer* [Pil15]. The study by Jeng *et al* [JDHL15] and a previous publication [GWW11] show that postings on an ASNS differ from postings on general social network sites: Content contributions demonstrate the characteristic of *academic writing style* including scientific terminology, well-cited resources and ground theories. The following section will take a brief look at current ASNSs.

4.3.1 ResearchGate

ResearchGate (http://www.researchgate.net) is a social network site for academics and has been founded in 2008. By 2016, the ASNS has over 9 million users sharing their scientific knowledge and expertise. The platform focuses on collaboration of scientists from all over the world [Res16]. To join the network, a valid email address of an academic institution is required, which should help to keep a high academic standard [JDHL15].

The content on ResearchGate includes scientific publications, statistics about readings and citations, job offerings and a *Question and Answer* system. Figure 4.2 shows a screenshot of the platform and its Questions & Answers. There is no content about the general academic life, like social postings about academic life, pictures of meetings or insights into the scientist's everyday life on ResearchGate [JDHL15].

4.3.2 Mendeley

Mendeley (http://www.mendeley.com) has started in 2008 and is a popular academic social network page with over two million users. It is a personalised research library that allows users to import PDF-files, organise the publications, connect with colleagues and manage all references. Around this catalogue a social network has been built. A researcher's profile, private as well as public groups are the features that help to build scientific connections all over the world. Mendeley also offers a desktop application and provides free web space

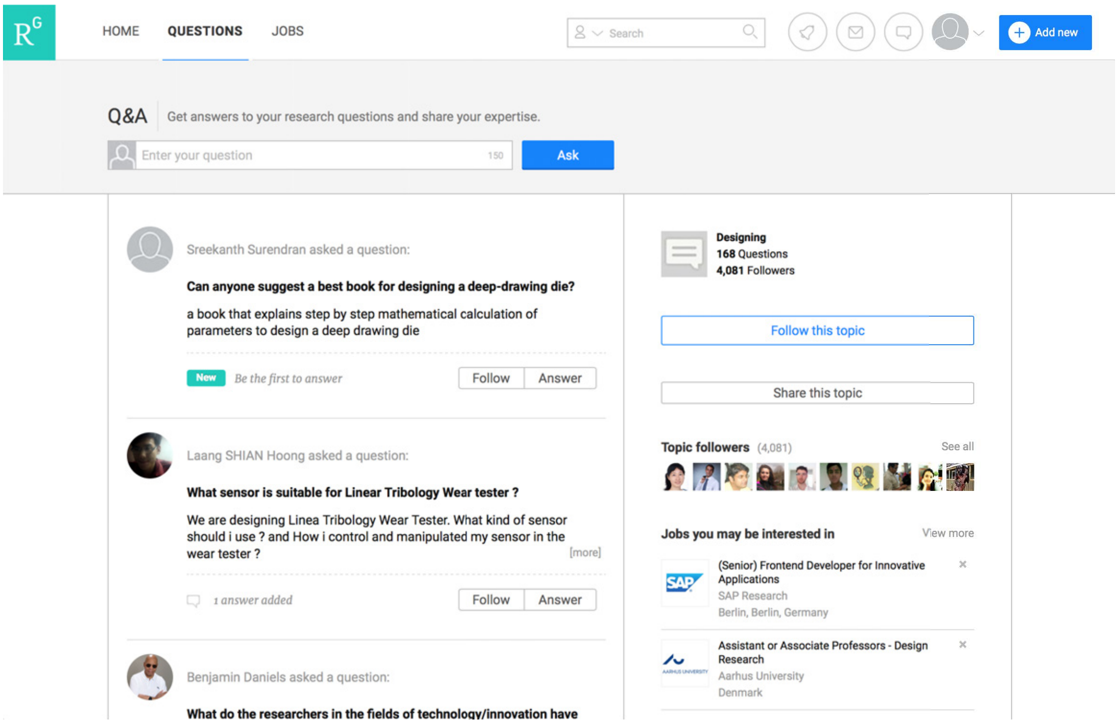

Figure 4.2: Screenshot (taken on 2016-05-28) of `https://www.researchgate.net/topic/designing` showing questions asked to the community.

for online storage [JHJ15]. Figure 4.3 shows a public *HCI* group on Mendeley that collects papers on mendley.com.

Following the results of a study by Jeng *et al* [JHJ15], the majority of users are junior researchers that use the platform more as citation manager than as a social network. Only 11 percent of the participants make use of the networking features to stay in contact with scientific friends.

4.3.3 Academia.edu

Academia.edu (http://www.academia.edu) is a social network community for researchers. It focuses on sharing research work and publications and tries to *»accelerate the world's research «*. By May 2016 almost 38 million scientists, researchers and academics have singed up to share their over 12 million published papers. Academia.edu also offers the feature to post paper drafts on the platform, asking for community feedback. Figure 4.4 shows this feature of collaborative work. [Aca16]

In 2013, Thelwall and Kousha [TK14] reported a lack of research that tries to investigate the impact of Academia.edu on science communication. They took a look at the role this online community plays in the field of scholarly communication. Their publication could not report

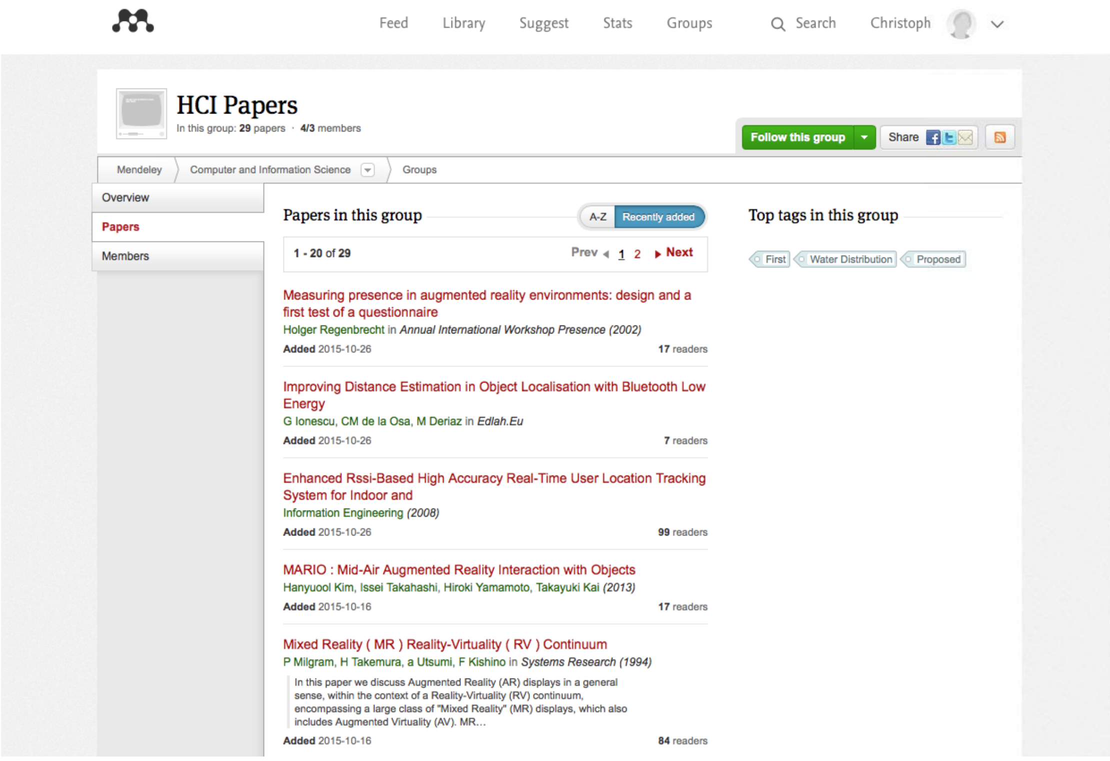

Figure 4.3: A public HCI group with papers on mendeley.com

a high correlation of their network with traditional research metrics, but underlines the value of a scientific communication and knowledge exchange.

A recent study by Academia.edu shows that publications on their platform receive 69% more citations after five years (16% after the first year). Additionally, in a timeframe of five years, a publication on this specific social network site boosts papers by 58% in the number of citations, compared to a simple posting on personal homepage and institution webpages [NVP+16].

4.4 Incentive Mechanisms & Motivating User Participation

People use the Internet with its unlimited variety and opportunities in many different ways. In particular, social media applications show that users do not always share the same motivation to participate. We like, comment, share, connect with friends, work, play, learn and publish. But what is it that drives our desire to stay close to such online communities? Since the advent of social network applications, Julita Vassileva [Vas12] has been researching this question. She came up with several approaches influenced by social psychology and behavioural economics.

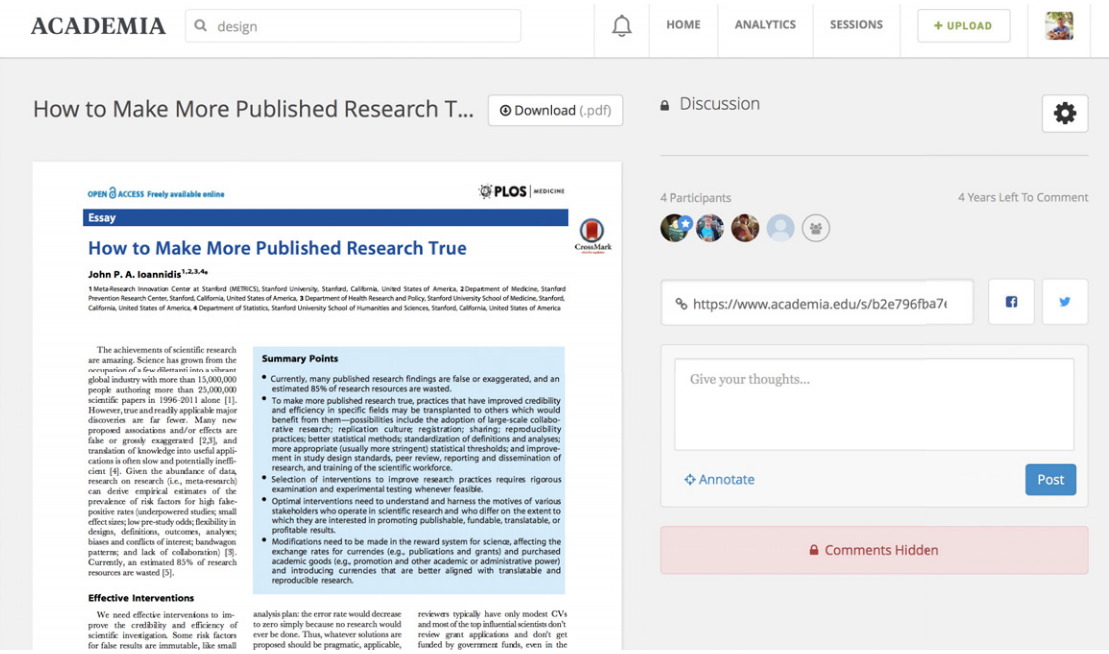

Figure 4.4: Asking for collaborative feedback to a paper draft an Academia.edu. Screenshot taken at 2016-05-28.

4.4.1 Motivation

Over the last years, many different social network sites have been sprouting out of the ground and almost the same amount has disappeared within a short period of time. Today we define our online behaviour as sharing our lives with different communities. We contribute and consume. We participate. But social media communities are facing a problem that is termed *under-contribution* by Ling *et al* [BLW+04]. Even successful platforms have to deal with this drawback. Therefore, it is a real challenge to design a community site that keeps the contribution process alive. A successful online community platform has to provide mechanisms to motivate the users to join *and* to stay active. A proper framing of uniqueness and a well-communicated benefit combined with goal-setting can help [BLW+04].

4.4.2 Incentive Mechanisms

In classical economics, people are seen as agents that act based on rational decisions to maximize their personal payoff. In order to motivate users to participate in communities, one has to find a mechanism providing rewards and incentives. The so-called *incentive mechanism design* approach is set up like a marketplace. A kind of virtual currency helps to balance the supply and demand of resources. Several challenges arise when it comes to issues like inflation, dynamic adaption, or non-tangible goods like knowledge distribution. In 2001, Greer *et al* experienced these trade-offs when they where researching a project called *I-Help* that encourages students to help and receive help at any time [GMV+01]. Furthermore, Vassileva mentions the open question of how much a system should reveal of its underlying economic model. People might exploit the system on their own interest, rather than in the interest of a common development of the community [Vas12].

A famous example of using incentive mechanism to generate user contribution was one of the early large-scale communities by Google called *Google Answers* that has been dropped in 2006 [Goo16]. The motivation was real money. People could ask questions, negotiate the price with researchers and pay for the answers. However, these real dollars have been the downfall of the system as it got exploited.

4.4.3 Gamification Approach

Gamification describes a design approach that has been coined by media industry starting in 2008. Deterding *et al* first proposed a definition of this term in an academic context:

> *»Gamification is the use of game design elements in non-game contexts.«*
> (Deterding *et al* [DKND11])

In a detailed discourse, they explain the distinction from playful interactions. In contrast to *serious games*, gamification only uses *»elements of games that do not give rise to entire games.«* This design approach should not be restricted to a specific context or purpose as *»non-game context«* is a very broad scenario. Referring to Detering's findings, a gamification approach makes use of different incentive mechanisms like they appear in real games (e.g. badges, rewards, different levels of difficulty,...). It also includes conceptual models of designing a game as fantasy, curiosity or challenges.

These game mechanics can also be applied to communities. As Vassileva points out, there are different game design patterns that influence the user participation in online communities [Vas12]:

- **Ownership**: People are motivated to keep being active in online communities if there are mechanisms that create loyalty. Owning points, badges or other things supports helps to achieve this.
- **Achievements**: Achievements are a good way to provide a reward for a goal that a user (or a group of users) has achieved. They are a physical or virtual acknowledgement that something special, difficult or funny has been done.
- **Status**: Status is an opportunity to present the individual's level to the community or even the public. It enables a ranking and personal integration.
- **Reputation**: Many users rely on the others' opinions. Amazon, eBay or other shopping platforms show how user reputation does have a serious impact on the individual's behaviour.

These different approaches and mechanisms can be found in the following prototypes that have been developed in an explorative design process, although it was not the main goal to specifically design a prototype according to the gamification approach.

CHAPTER 5

Design Process

5.1 Prototype 1: inLab

The practical implementation of this thesis started with an explorative approach to implement an online community platform for science communication. A first concept within this design process represents an idea that focuses on open innovation and citizen science. It involves non-scientists' projects that need support in any kind of expertise, including scientific advisory. A community website helps to organise these projects and crowdsourcing.

As many crowdfunding and crowdsourcing communities like *Kickstarter*[1] or *Indiegogo*[2] demonstrate, this first idea tries to bring the *power of the crowd* to a scientific context. InLab starts with a broader approach to people's projects in general and tries to put emphasis on their scientific need within their progress to reach their goals.

At this very first stage of the explorative design process, mock-up designs and a prototype implementation (using the Django framework[3] and Python programming) have been applied.

5.1.1 The basic idea

People can share their innovative projects on an online platform called *inLab*. This thought of open innovation leads to a beneficial opportunity for both the projects and the public. To demonstrate this idea, a simple user workflow (see figure 5.1) is defined that should encourage people to easily share their innovative projects and challenges with other interested people.

A process of four steps helps users to connect with others and make the best out of their projects:

[1] http://www.kickstarter.com
[2] https://www.indiegogo.com
[3] https://www.djangoproject.com

1. **Start your project**
   Users can easily create a project on the inLab community platform. A project page with basic information including project title, description, project team and goals helps to communicate with the public, without the effort of creating a standalone website. Project teams can use this representation to share their progress, challenges, news and achievements.

2. **Define challenges**
   Innovative projects face a lot of challenges that cannot be solved by the project team. Inspired by ideas of *crowdsourcing* and *crowdfunding*, inLab offers the possibility to ask for external help. Projects can define so-called *challenges* and outsource certain tasks in order to succeed. See *5.1.3 Challenges* for detailed explanations.

3. **Inspire contributors**
   The community platform focuses on encouraging interested users and experts to help the project team to solve certain challenges. Again, the project page introduces the project setting, acts as public representation and will be used to explain the needs and benefits of external help. There are social media integrations (e.g. like and share buttons) to extend the reach. Different tags, areas of expertise or location-based parameters enable challenge and project discovery.

4. **Connect creativity**
   Finally, the connection of new creative inputs enables new possibilities. Expert's feedback and collaborative ideas help to be innovative. The platform connects projects with people that can offer a solution, an advice or a helping hand.

All of these four stages of the initial concept include social media activities to focus on science communication aspects. The touchpoint of existing social media platforms (like Twitter, Facebook,...) allows to gain a broader reach and find an interested target group. The inLab page lists achievements and news updates about the project to always represent the latest state of the project.

5.1.2 Public Project Pages

In line with the motivation of *open innovation*, users can create projects on the inLab platform. Projects represent the community website's central aspect. Once a project is activated it becomes public. This means that even non-members can see the project page and the challenges on the platform, because this might motivate others to contribute. A simple wizard helps the project creator to customise the project page (project title, project location, project logo, project graphics, project description). This project representation is used to act as a simple way to create a first project homepage without any prior web-design knowledge. The public project page is an overview to show all information and updates about the project. Figure 5.4 shows a prototype implementation of the project page.

The project page's design is influenced by common patterns that appear on crowdfunding platforms. Figure 5.2 shows two example screenshots of Kickstarter and Indiegogo. Both

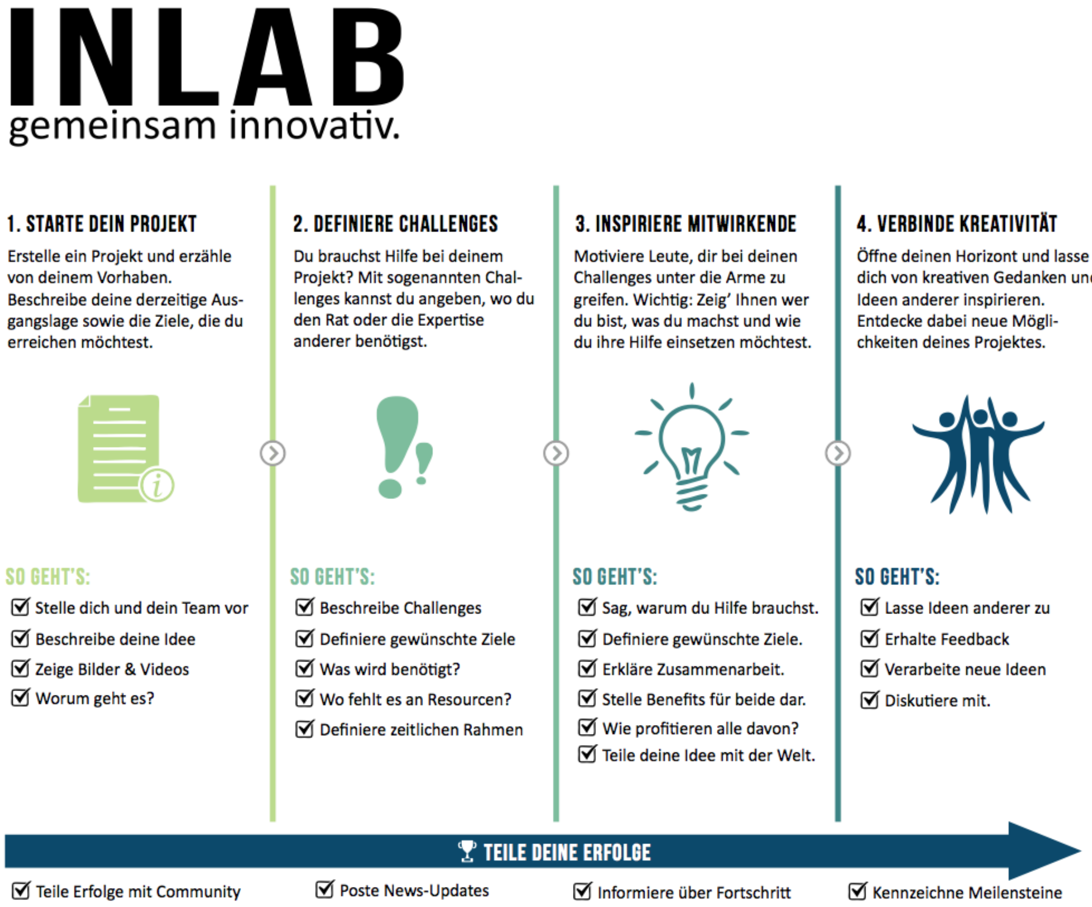

Figure 5.1: Initial user workflow of inLab.

community pages have in common that they use almost infinite scrolling mechanisms to present very detailed and a lot of information about the project. This information is shared to attract interested people's attention. The linear sequence of multimedia content (that can be individually arranged and resembles a *stream*) got picked up in the basic idea of the project page design of inLab.

5.1.3 Challenges

Having set up a project page, the owner can now define so-called *challenges*. These challenges represent the point of contact on the community platform. Project owners define their needs (e.g. lack of knowledge, need for help, support,...) and publish it on the project page with the goal to find a supporting member. Platform users can browse for different projects based on interests and location and offer their help to specific projects. Figure 5.5 shows a list of *open* (unsolved) challenges. A simple click on the *»I can help«*-Button connects project

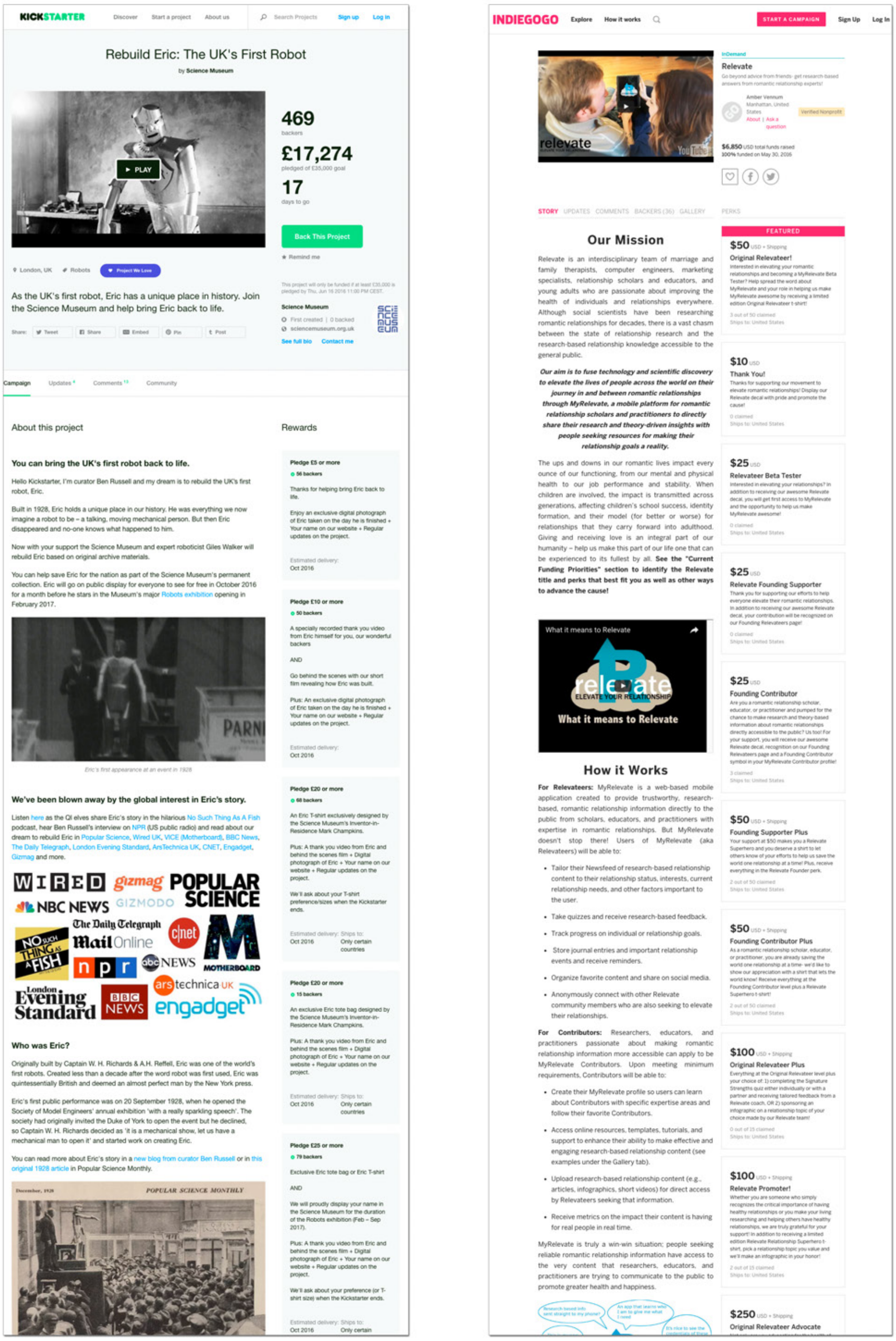

Figure 5.2: Project page screenshots of kickstarter.com and indiegogo.com taken on 2016-05-30 to demonstrate detailed descriptions and extent of shared information.

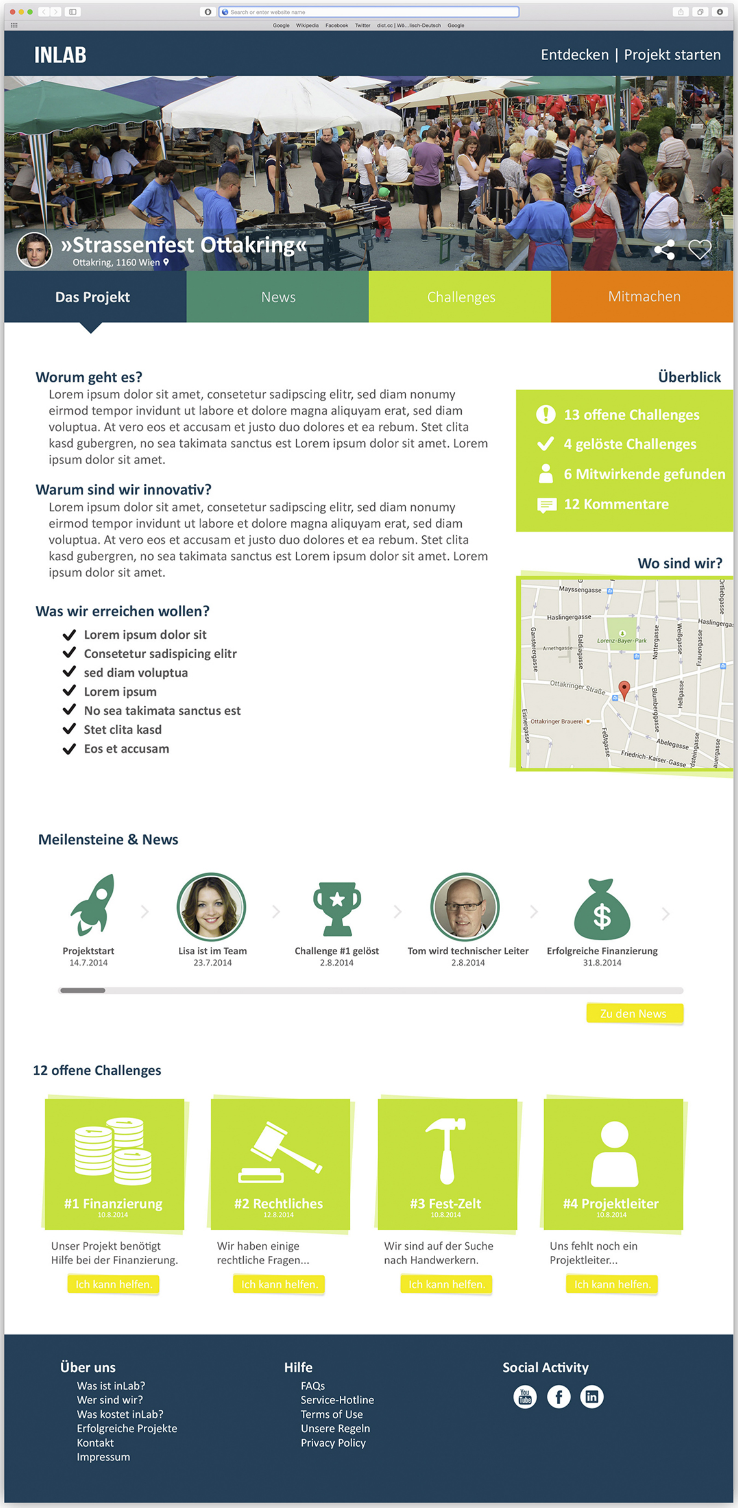

Figure 5.3: Prototype implementation of a project on inLab.

Figure 5.4: Homepage of inLab platform.

Figure 5.5: Challenges on project page

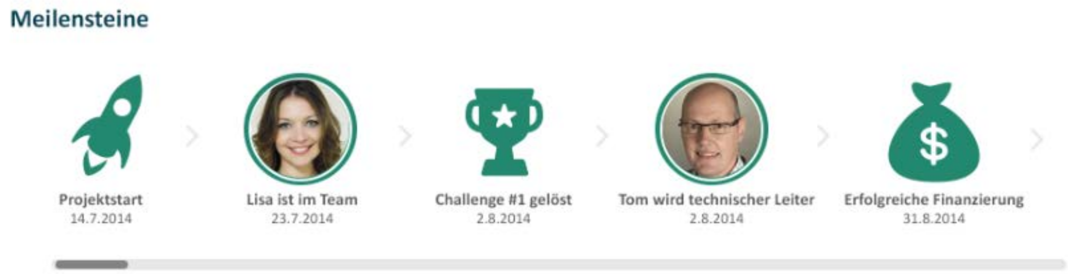

Figure 5.6: First draft of inLab's milestone timeline.

owner with potential project supporters.

5.1.4 Milestones & Project Timeline

Besides representation, the project page should act as a progress documentation tool. Project members, supporters and users are able to track and follow the development of the projects. *Milestones* help to communicate important steps in the progress and make the current state easily comprehensible. Figure 5.6 shows a draft of a project timeline bar within the first concept. There will be a more detailled discussion about timelines in section *5.2 Prototype 2: snap.science*.

The first conceptual prototype platform includes different kinds of milestones that can be created both manually or automatically. Exemplary milestones are: *Challenge solved*, *user entered project* or *Funding complete*. These milestones represent the most important project events.

5.1.5 Scientific Advisory

In order to make the platform stand out from other crowdfunding and -sourcing sites and to fulfil the goal of creating a science communication tool, scientific advisors can help projects to succeed. Therefore, project owners can create *science challenges* to ask for scientific advisory. Researchers and experts can browse these challenges and offer their help to the projects. The extent and conditions of this cooperation depends on individual agreement.

A possible implementation of this idea could be a system similar to *coupons*. If a researcher or scientists was interested in a project and could imagine to offer help, he/she could assign arbitrary amount of *scientific advisory* (e.g. 4 hours of discussion). Project teams could redeem these coupons to include scientific opinions.

5.1.6 Drawbacks & Concept Changes

The first concept of inLab includes science communication aspects only to a very small extent. Projects could ask for scientific help just as they could ask for physical support, for example. However, the focus on communicating science gets lost. The role of science and expertise knowledge is something that would have been kept inside the project context and would not be presented to the public. Although innovative projects could join the platform, the concept is more addressed to support crowdsourcing rather than scientific projects.

In addition, the concept relies on the individual scientist's motivation to pro-actively search for projects that can benefit from his/her help. It assumes that scientists want to share their knowledge with the public without gaining a personal benefit (like financial incentive). In order to push science communication to a new level, the platform should involve researchers not online as external problem solver. An insight into their work and daily findings would not be possible with a platform like inLab.

However, the open innovation character allowing everyone to join and the simple project presentation for representation were features we have learnt from and appreciated in this approach. After this first prototype implementation we have decided to focus more on communicating science to enable a scientific insight for the public. This leads to a new discussion about science communication that really wants to capture the workflows of research.

5.2 Prototype 2: snap.science

Prototype 2 of the design process follows a method suggested by Ron Wakkary [Wak03] to *rush* into a prototype that can be tested in a real-world setting. Therefore, *snap.science* is implemented as an online platform (using the Django Framework, HTML, CSS, Python and Javascript) and evaluated with user feedback and field-testing (see chapter *6 Evaluation*).

5.2.1 Motivation

Having started with a citizen science approach (prototype 1), we faced the problem of not gaining enough insights into real scientific work. Asking for scientific help may be beneficial for citizen science projects, but does not help to increase the public awareness of science as the goal of this thesis is. Therefore, a new idea trying to encourage researchers to share their everyday moments and experience had to be found. Scientists work with the latest trends in their field of expertise. These insights should be reflected and shared on a platform to share it with a public audience. However, this tool should not consume the researchers' time and focus. Non-scientists often do not have the chance to understand what science is doing. Long-term paper review processes and publications behind paywalls [Wil12] exclude the public from participating in the progress of scientific projects. Prototype 2 introduces a method allowing the public audience to follow the daily routine and latest insights. Projects in a science context automatically create a public representation of their work in progress and results. This generated *stream* and project information takes up the first prototype's finding and implements it with another perspective.

5.2.2 The Concept of snap.science

The new prototype is initiated with idea generation methods, sketching and low-fidelity mockups. Figure 5.7 shows some early drafts of the concepts in the design process.

Prototype 2 - which has been named *snap.science* - has two main features. First, researchers and members of a scientific project can easily collect, share and document their everyday insights with photographs and other postings. This content acquisition is an easy process and does not distract from doing the real job, as simple web interfaces can be accessed via mobile devices. Second, public users and visitors can browse the feed and get a real-time overview of the projects' progresses. Snap.science is an online platform where researchers create a public project page in which the content grows with the everyday workflow. This project page acts as representation tool in order to gains insights.

5.2.3 User roles

Before starting to implement the prototype, essential user roles were identified:

- **Project Owner (registration required)**
  A project owner is a researcher who creates a project on the platform. He/she can edit

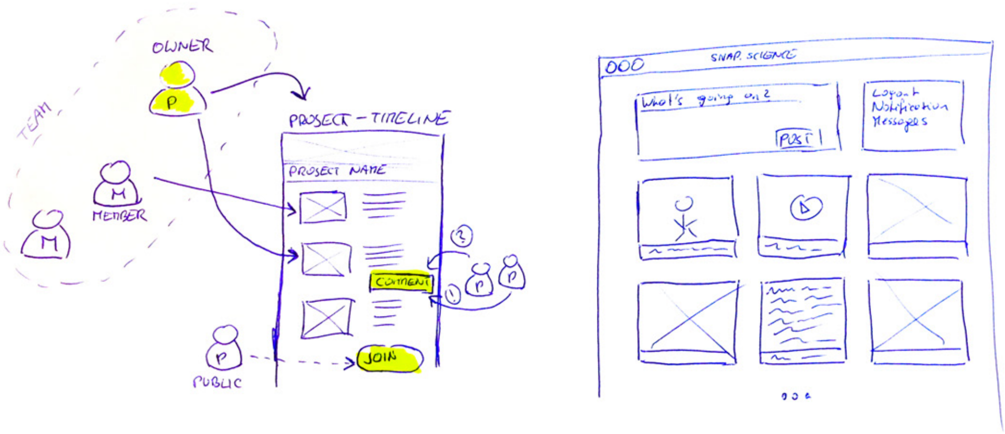

Figure 5.7: First conceptual draft of prototype 2: snap.science.

the project's timeline and is responsible for content administration and meta description (including project title, project header image, location, description text,...).

- **Project Member (registration required)**
  A project member is a registered user that works in a research project. To contribute to the project timeline, a user has to join the project first. This assignment needs the role of the project member to be complete. A project member's role could be researcher, interviewer, interviewee, founder, etc.

- **Public Visitor (no registration)**
  All public visitors can browse the timelines of the projects and see all public postings related to the projects. Any kind of interaction with the project members requires registration.

- **Public User (registration required)**
  A public user is someone who is not involved in a project but wants to follow the projects. In addition, he/she can interact with the projects via comments and likes.

5.2.4 User Stories of Functional Prototype

This prototype of the design process has been implemented to test it with real users (see chapter *6 Evaluation*). Therefore, basic user stories are covered. It was not the idea to fully implement the web platform in every detail. The following list gives an overview of implemented user stories to get a first functional prototype. This extent lays the foundation for the following user testing setting.

- A public visitor registers to be a public user.

- A public user logs on.

- A public user creates a research project to be a project owner.
- A project owner edits project information that is shown on the project timeline.
- A public user joins a project to become a project member and to be able to post on the project timeline.
- A project member posts something to a project timeline.
- A public user comments on a project posting.
- A public user likes a posting.
- A public user gets alerted when someone has commented on his/her posting.

5.2.5 Development Environment

The snap.science prototype was built as a web application using the *Django Framework* [dja16]. Django offers an open source, high-level, Python based framework to easily build webpages and is a perfect approach for rapid prototyping. It is addressed to focus on the application without reproducing well-known and often needed code.

Front-end programming techniques include HTML(5), CSS3 and JavaScript. The back-end solution was built with Phython (as Django is a Python framework). The development environment also included a MySQL database for data storage.

All front-end layouts and HTML templates apply responsive techniques. *Bootstrap*[4] - a popular framework including HTML, CSS and Javascript - supports the idea of *mobile-first* development. Snap.science is developed to enable easy and especially mobile content creation. From the very beginning, cross-platform and mobile access to the site has been a requirement. Figure 5.8 shows a screenshot of the platform accessed via a smartphone. All designs and layouts that follow are designed to work in both desktop and mobile version.

5.2.6 The Postings

Having looked at scientific workflows and having talked to researchers, we introduce different posting categories for content updates. These differentiations are made to get diversity and express the range of different aspects of science. The post creator on the web application shows these six categories (see figure 5.9):

- A **WOW Moment** is something interesting to the researcher and reflects the pioneering character of research.
- A **Social Moment** captures cooperation and team work and highlights collaboration in a scientific setting.

[4]http://getbootstrap.com

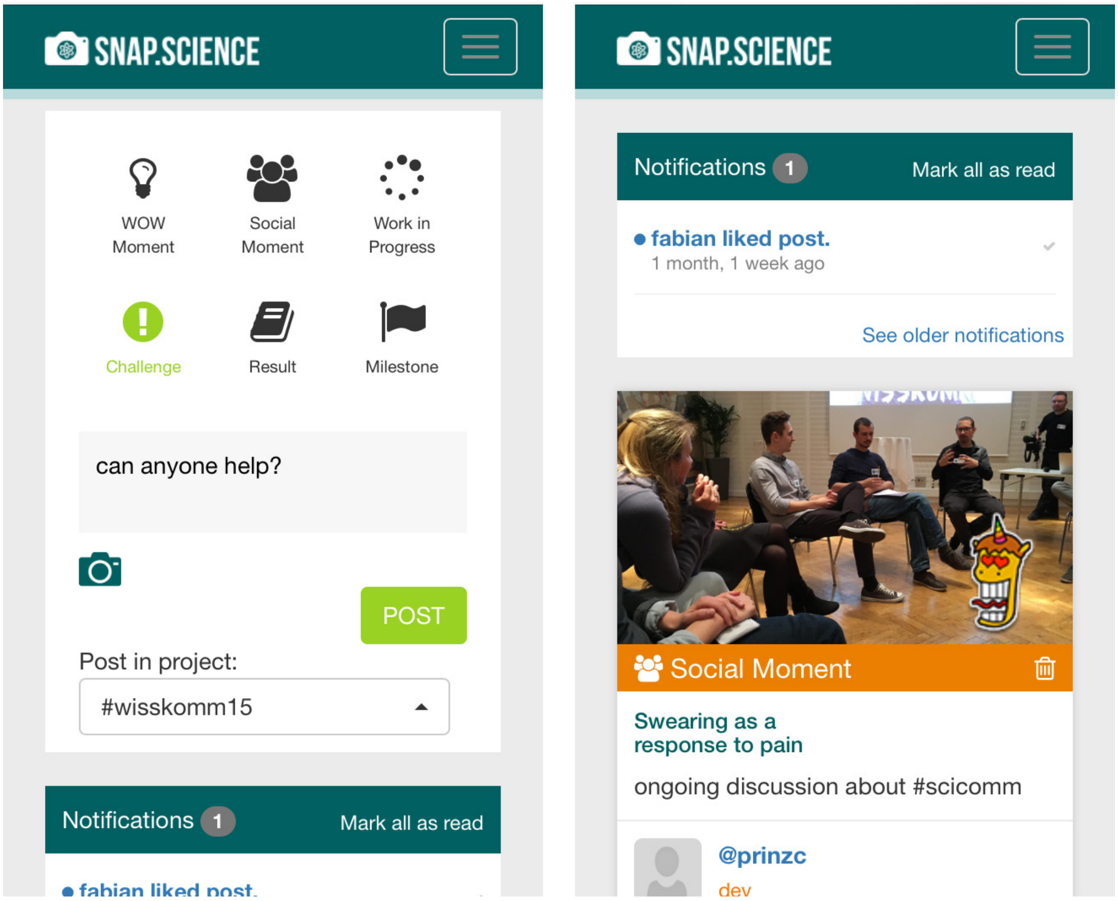

Figure 5.8: Snap.science: responsive design layout.

- **Work in Progress** documents project progress and documents daily work.
- A **Challenge** represents an open question and encourages other users to contribute.
- A **Result** posting shows outcome, effects and publications.
- A **Milestone** documents essential partial success and highlights project progress.

5.2.7 Look & Feel

In a next design iteration, the look and feel of the platform is discussed. Figure 5.10 shows two inspirational platforms including user postings. A very minimalistic design approach of these websites allows to concentrate on the user generated content. Snap.science follows the idea to combine a flat design with a trendy and fresh attitude. The content of the scientific postings should be in focus while showing the variety of research. This idea gets expressed with the chosen colour scheme.

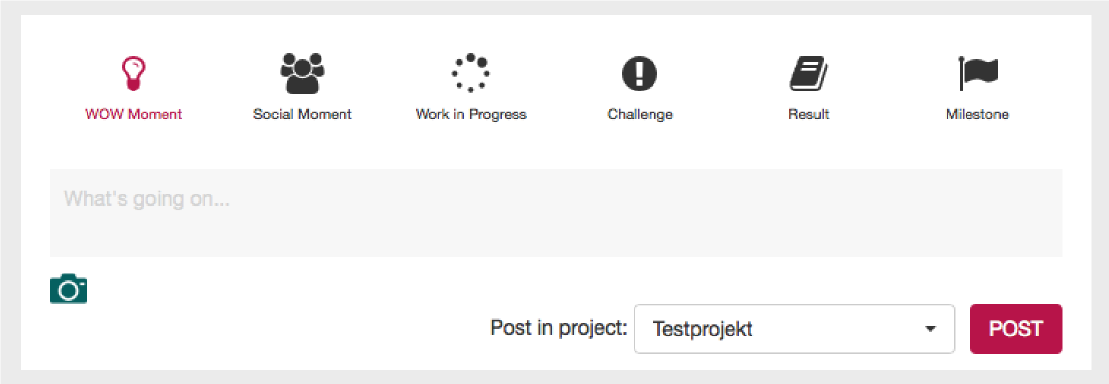

Figure 5.9: Implemented post creator module of snap.science application.

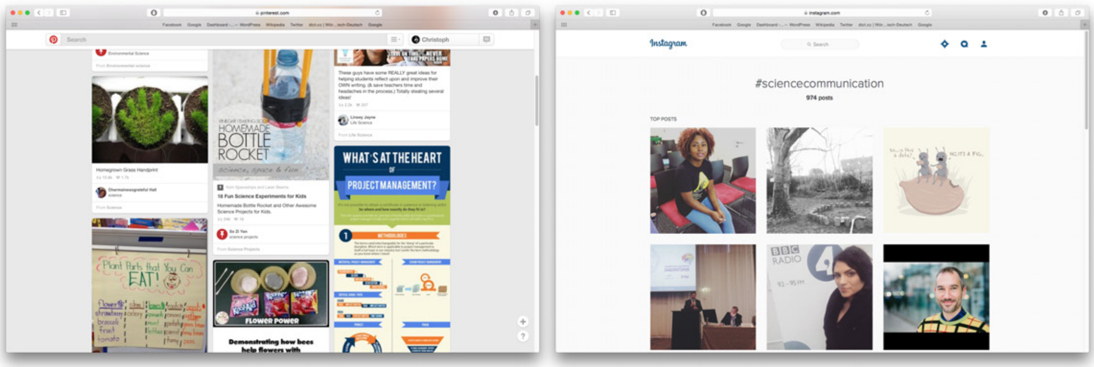

Figure 5.10: Inspirational looks and platforms for snap.science. Left: Pinterest (www.pinterest.com) Right: Instagram (www.instagram.com). Screenshots taken on April 20, 2016.

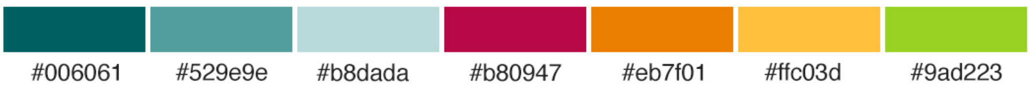

Figure 5.11: Colour scheme of snap.science

The inspirational platforms and the colour scheme are used to design a first mockup of the new platform. See figure 5.12.

5.2.8 Stickers

It is obvious: online communication has gone far beyond textual communication. Pictures, videos, stickers and emoticons offer the tools to create what Sun Sun Lim calls *»communicative fluidity«* [Lim15]. They allow to express emotions and feelings and help to show our intentions. With these litte pictorial helpers users can shape their conversion more seamlessly and smoothly.

Different intentions of content updates on snap.science can be expressed with different posting categories (as described in *5.2.6 The Postings*). In addition, comic stickers have been created to emphasise these intentions and feelings while experiencing science. Users can add stickers to photo updates of their project. The set of stickers includes a limited selection of common *meme*[5] emotions. Figure 5.13 shows the set of stickers and a posting with a sticker on the snap.science platform.

5.2.9 Project Pages & Timeline

The prototype implementation includes a project representation feature. With the content of all individual project members, so a project page can be generated automatically. This project page allows visitors and interested people to follow the project's progress. While the landing page of snap.science shows a grid of all postings, the project page should underline the postings' chronology. Three different timeline mock-ups have been created in order to consider different approaches to present timeline data.

3D Timeline
The first timeline style implements a three-dimensional approach, as figure 5.14 shows. The underlying idea is to enable users to virtually go through the project's progress. Recent content will be displayed in front and older content will disappear over the horizon. The user can go back and see older postings by scrolling through the timeline. This kind of timeline requires a large screen to see and recognise older content. The information provided by the third dimension is not particularly needed. Therefore, this draft is considered to be not appropriate for mobile devices and gets discarded.

Mobile Timeline
In a second step, a mobile version of the project's timeline is developed. In this design iteration the individual's content attribution and personal timeline are focused. Figure 5.15 shows both a landscape and portrait version of a smartphone application. The mobile timeline shows small thumbnails of actual postings. By tapping the small thumbnail a full screen posting will be displayed. Each row represents the timeline of one single user (or project). Every

[5] A *meme* is »an image, video, piece of text, etc., typically humorous in nature, that is copied and spread rapidly by Internet users, often with slight variations.«Definition by Oxford Dictionaries (http://www.oxforddictionaries.com/definition/english/meme) accessed on April 20, 2016.

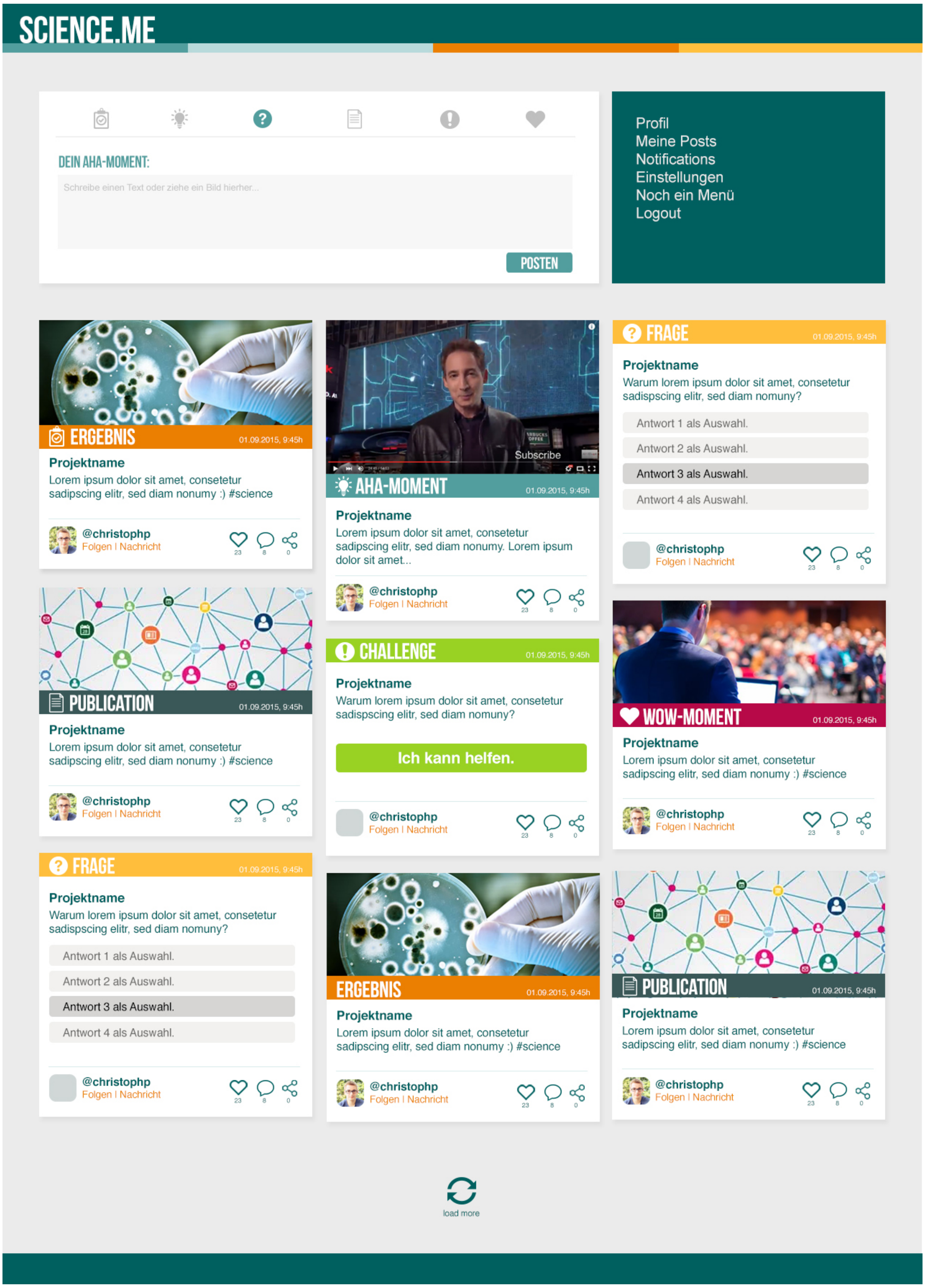

Figure 5.12: First mockup design of snap.science

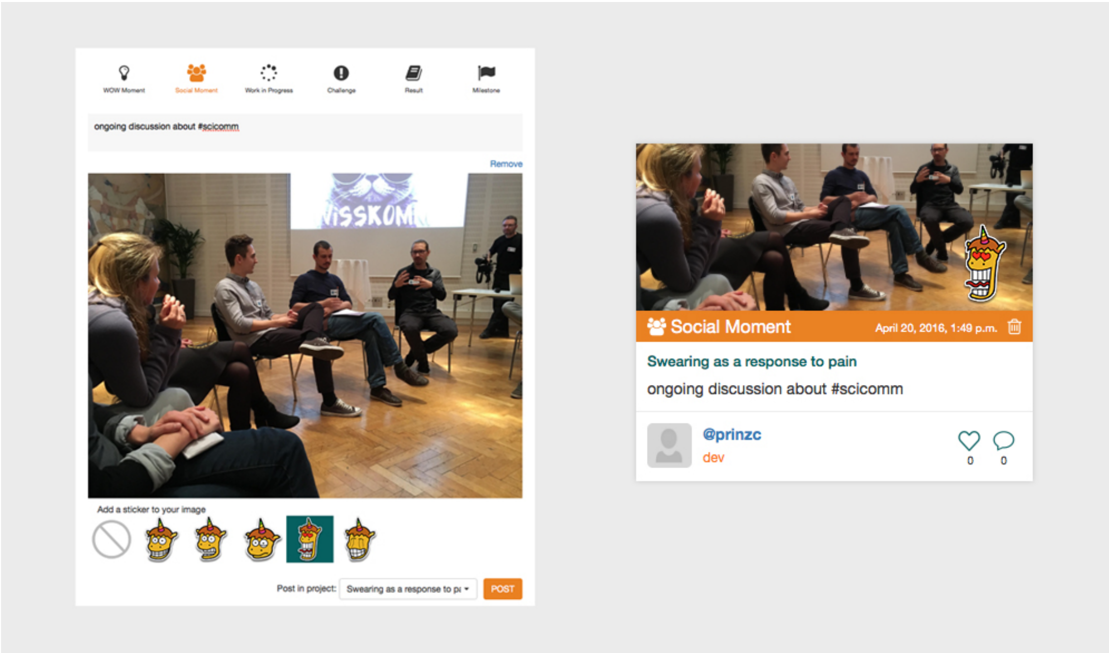

Figure 5.13: Post creator with sticker selection (left) and posting with sticker in stream (right).

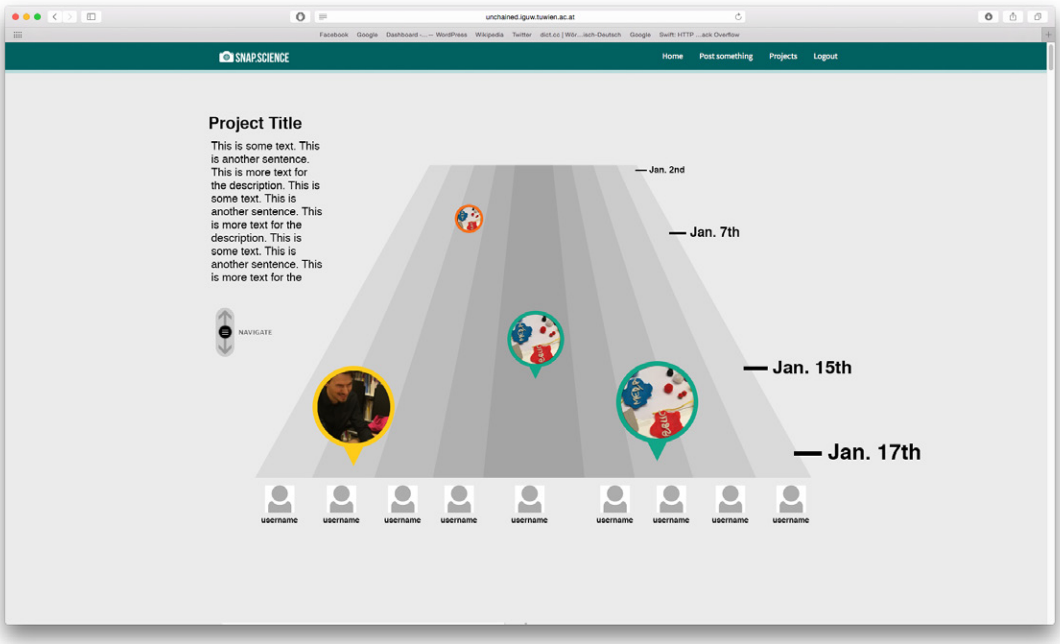

Figure 5.14: First timeline mock-up: Three-dimensional approach.

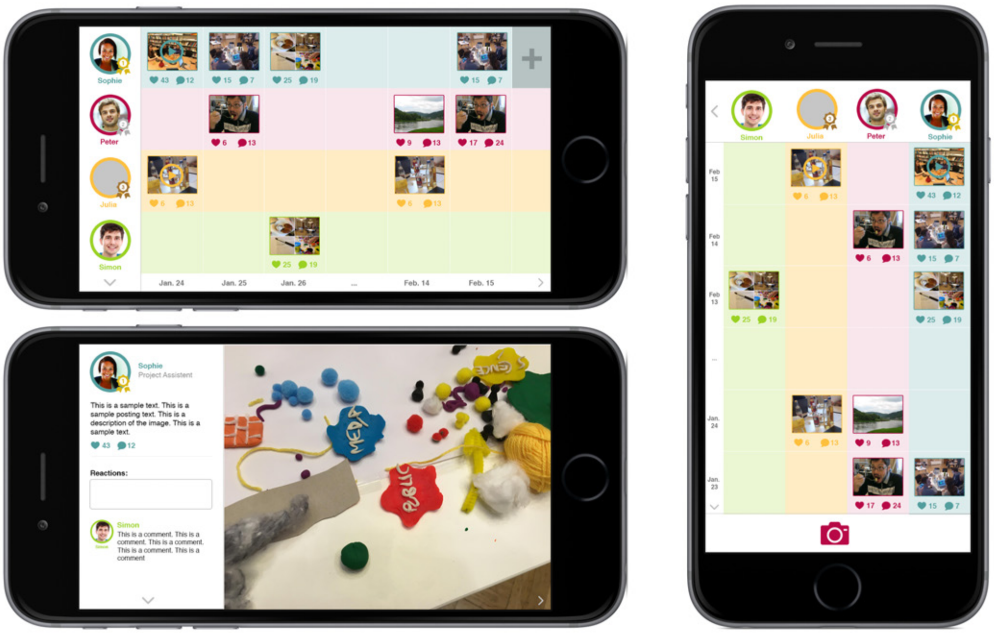

Figure 5.15: Mobile timeline mock-up for snap.science.

column includes a single day. Multiple postings by a user on the same day will be grouped. This kind of timeline gives a good overview of the individual's activity on the platform. Long absence and low posting activity will result in a very fragmentary timeline representation. The fact that this style shows the gaps in the timeline makes us discard this approach.

Linear 2D Timeline

Finally, a classic two-dimensional timeline is designed. The left sketch of figure 5.16 shows an early draft of this multimedia timeline. Different kinds of media (e.g. texts, photos, galleries, videos,...) can be included. The vertical expansion shows a clear, linear time history. This kind of timeline is implemented in the prototype version, because a responsive version of this timeline makes it accessible and usable on smartphone devices, too. Figure 5.16 (right side) shows an actual project timeline with user postings.

5.2.10 Mobile Application

As the evaluation of snap.science shows (see chapter *6 Evaluation*), the platform is mainly accessed via smartphones. Therefore, a mobile application (Android and iOS) is being developed. This application is assigned to this project but is not part of the thesis. The smartphone application covers the use case of uploading a posting after taking a photo.

Figure 5.16: First timeline draft (left) and implemented timeline of snap.science.

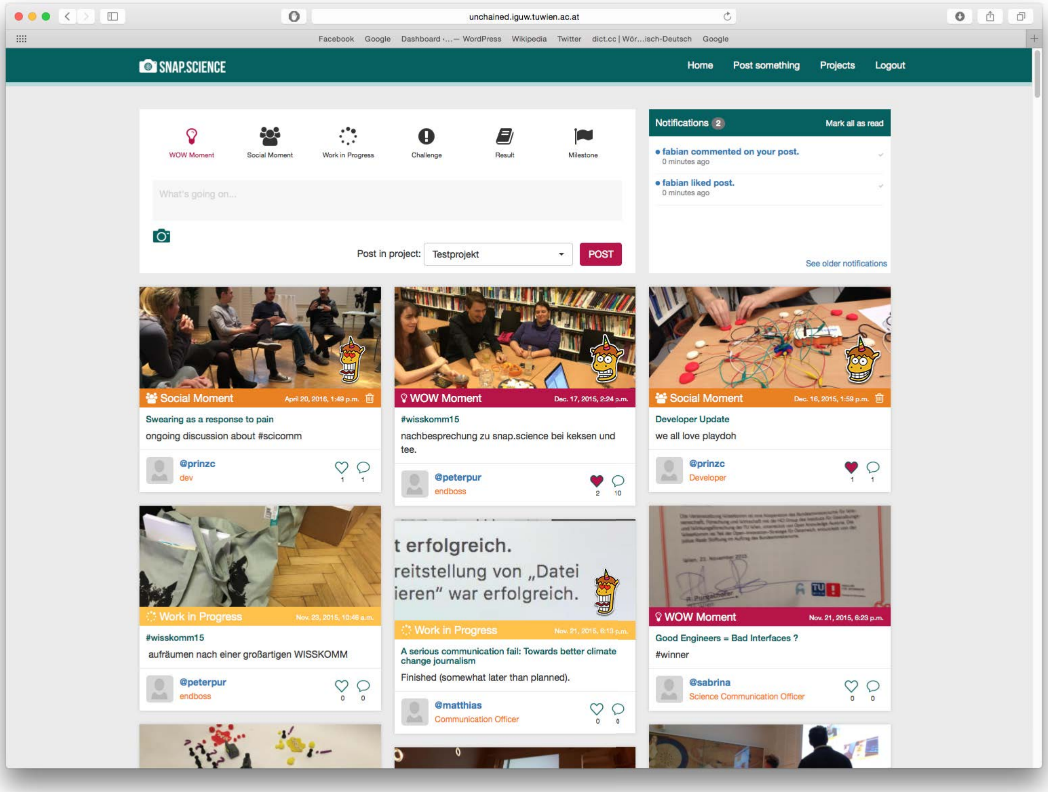

Figure 5.17: Screenshot of final prototype implementation of snap.science.

5.2.11 Prototype Drawbacks and Findings

Prototype 2 of the explorative design process shows an example implementation of a platform to instantly publish project insights. As the evaluation and the field test will show, users tend to not use different posting categories. Regarding to the results of the focus group, users want to be rewarded for content contribution. Besides documentation purposes, the concept of snap.sciecnce has a lack of incentive mechanisms for content contributors. The effort of publishing scientific insights should be rewarded with any kind of appreciation. Simple *likes* or comments - even when combined with a notification system - might not be enough to keep the community active.

These insights gained from prototype 2 lead to a new idea that focuses on a reputation system to increase user participation. Scientific expertise is an honourable good. This prestigious status symbol picks up the motivation of self-presentation to join social networks, as discussed in *4.2.1 Facebook - Virtual vs. Real Communication*.

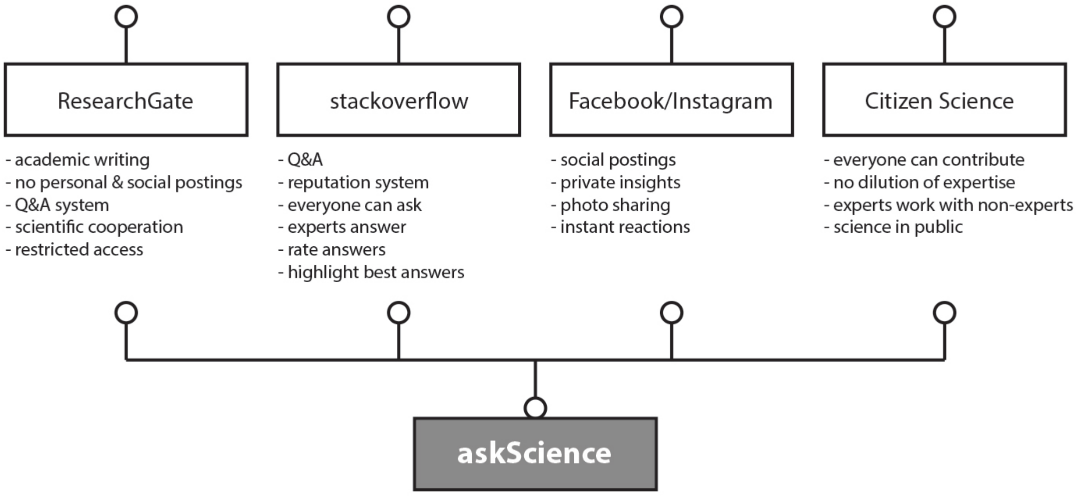

Figure 5.18: Conceptual influence of askScience

5.3 Prototype 3: askScience

Prototype 3 represents a new approach to increase the public interaction with science and offers a public expertise appreciation system to users.

5.3.1 Motivation & Idea Generation

This prototype approach tries to learn from successful and well-known platforms and combines these advantages with a focus on science communication in a new online platform. A brief analysis of four networks leads to the the concept of *askScience* as figure 5.18 demonstrates:

- **ResearchGate**
  ResearchGate has a clear target group: researchers and scientists. Profile updates are strongly related to scientific work. Postings have a very academic writing style. There is no room for social or private updates. An embedded Q&A system addresses other scientists and offers no possibility for non-scientists to join the conversation. This closed target group is underlined by a restricted registration access: an email address of a scientific institution is required to register on ResearchGate.

- **stackoverflow**
  stackoverflow.com offers an open platform to ask programming questions and is part of the Stack Exchange network. This question and answering system clearly focuses on a broad audience. Everyone is allowed to see the answers and can register to submit a solution. A reputation system encourages contributors and shows the best-rated answers. The idea that everyone, no matter what kind of expertise they have, can ask and experts provide answers inspired prototype 3.

- **Facebook/Instagram**
Facebook represents one of the most powerful and widespread social network sites in the Western world. Newly introduced reactions enable instant feedback with a limited amount of emotions. These fast reactions enable high interaction. In addition, both Facebook and Instagram focus on social postings and private insights. There is a strong tendency to make use of photo and video postings.

- **CitizenScience**
Although *Citizen Science* in general is no social network platform, this approach has an impact on this prototype. The concept of everyone being able to contribute to science while not diluting expertise is a central goal we want to achieve with this thesis. Citizen Science projects enable collaborations between experts (scientists) and non-experts (the public).

These insights gained from existing platforms result in a new prototype concept that will be introduced in the following sections.

5.3.2 The Prototype Concept

A website called askScience is a science communication platform open to everyone. Scientific questions and questions about research issues are the main driving forces of this network page. This tool enables non-scientists to get in touch with experts. Researchers and all other experienced users can communicate their expertise through their answers. A reputation system within the platform will reward contribution. A so-called *public science contribution index (PSCI)* indicates the appreciation of a user. askScience is a platform for everyone to access scientific expertise on the one side and a tool to get recognised for one's knowledge on the other side. The public accessibility of knowledge and the transfer for science to the public is in focus.

Besides individuals, askScience allows research projects to join the community. Projects can also ask questions and encourage other users to help. This idea picks up the first prototype's concept (see chapter *5.1 Prototype 1: inLab*) and applies it in a different setting.

AskScience's concept is implemented as a mockup design draft, as figure 5.19 demonstrates.

5.3.3 Science Questions to Drive the Community

So-called *Science Questions* represent the community's interactive driver. Both experts and non-experts can join a scientific communication. This enables an open access to everyone, in contrast to the Q&A network of ResearchGate.

There are two types of these questions: **general questions** and **project questions**. Project questions are related to a scientific project that is present on the platform. These kinds of questions can be connected and attached to any content project page, for example when a project publishes its latest news article and a visitor does not understand something.

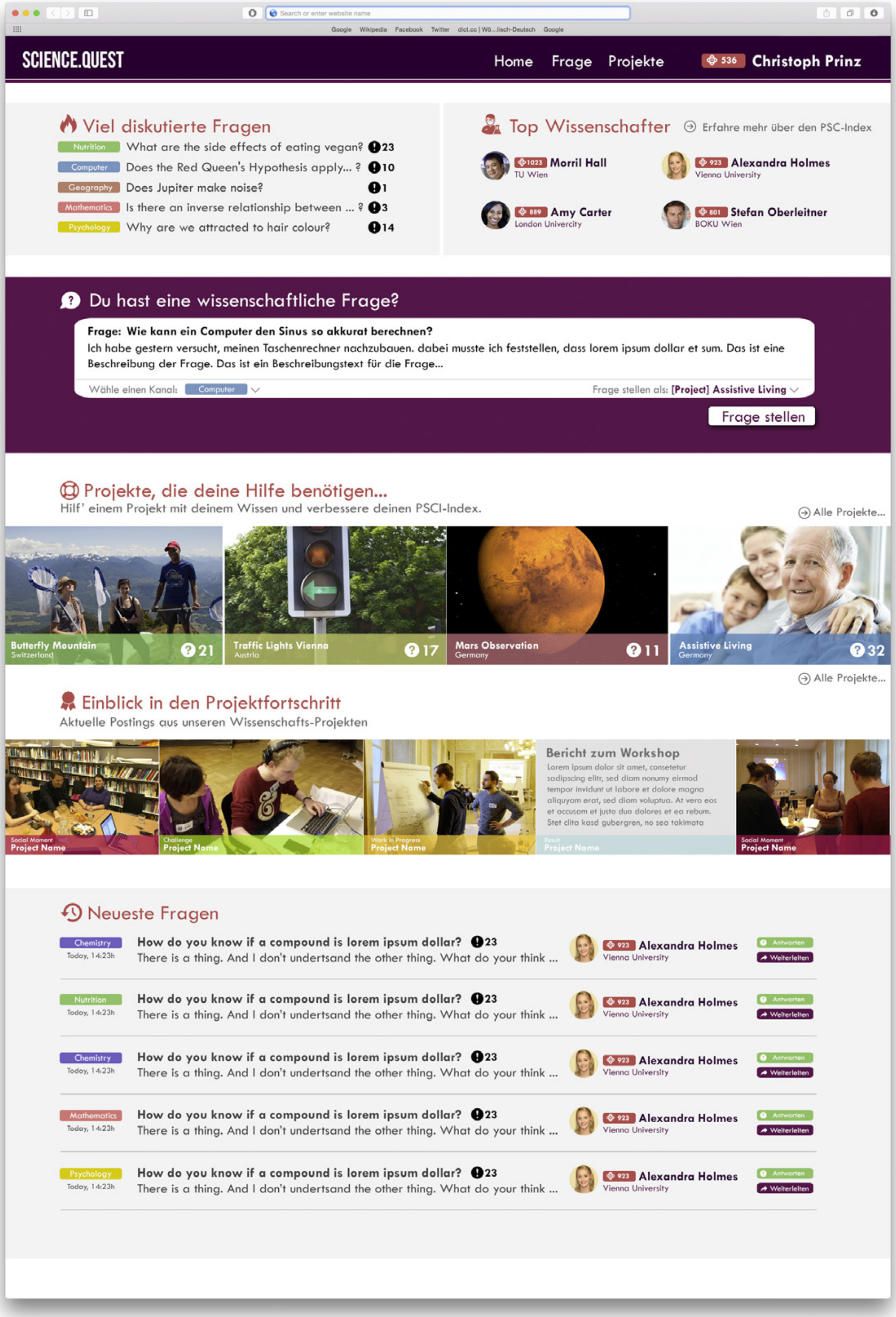

Figure 5.19: A mockup design draft of askScience

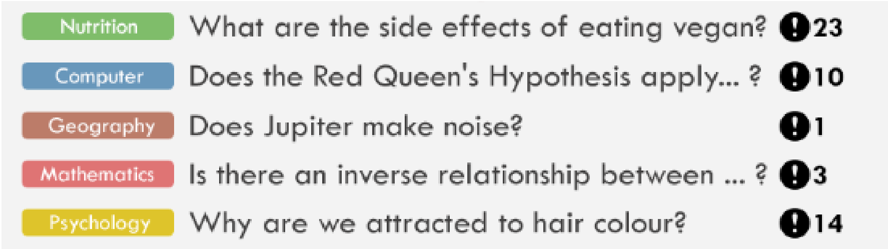

Figure 5.20: Categorisation and tagging system of askScience questions.

General questions address a broader audience and are related to a special area of studies. This categorisation is reflected in an optical and organisational tagging-system all over the website, as figure 5.20 shows. Project questions are also related to a specific subject and fit into this tagging system.

5.3.4 Social Reaction: Forward Questions

Scientific questions are open issues to people or project teams. The prototype idea is to connect users who have unanswered issues with experts who can help. But even users without an answer can help: The feature to *forward* a question enables users to encourage others to join the discussion. For example, a project team asks a question, because they cannot find the answer on their own. A registered user, who follows the project, sees the issue bus is not proficient enough in this area of knowledge to answer it correctly. However, this user can help by forwarding the question to someone he/she knows is an expert in this field. This recipient of the forwarded question does not necessarily need to be an active user. Email invitation or other social media integration can help to spread the platform and access external experts. Figure 5.21 demonstrates this kind of scenario:

1. A *User A* publishes a scientific posting/content.
2. *User B* reads it, but has troubles understanding it.
3. So *User B* reacts with a question.
4. *User A* receives this question, but is not able to answer it.
5. *User A* forwards the question to *User C*
6. *User C* receives this question and can answer it.
7. *User B* is happy to receive an expert's answer and understands *User A*'s posting now.

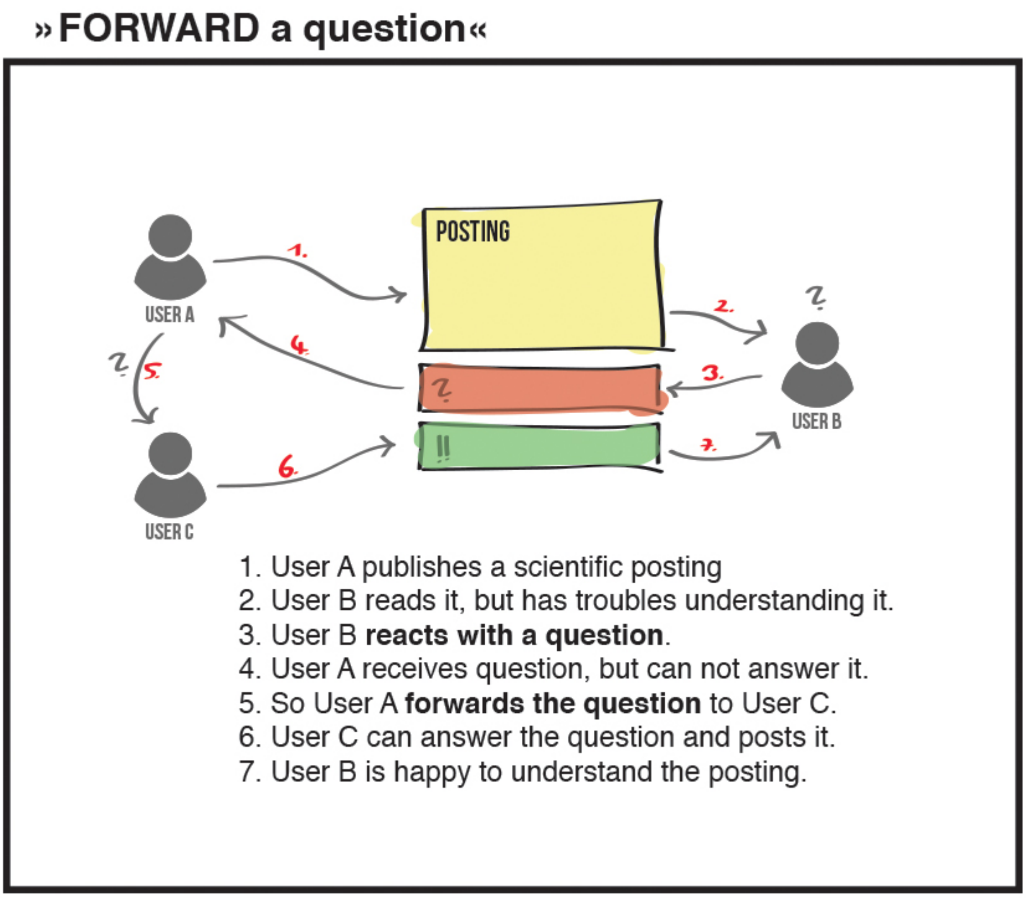

Figure 5.21: Use case of prototype 3: forward a question.

5.3.5 Public Science Contribution Index (PSCI)

askScience does not distinguish between scientists and non-scientists. There is a simple motivation: *everyone can do science. just show your expertise*. In order to measure scientific activity on this platform, the concept of askScience includes a *science reputation index* that values the public contribution. This metric is inspired by the well-known h-index (see *2.4 The h-index*) but also includes social media activity and online contribution on the platform (like altmetrics approaches).

Every individual can push his/her PSCI to gain public reputation on the askScience platform. Active contribution and interaction gets rewarded with a boost of one's personal index. For example, answering a question will give be credited with an index increase. If other users up-vote this answer to highlight it as a correct solution the author will be rewarded as well. Furthermore, forwarding questions or other contributions imply a positive effect on the individual's PSCI.

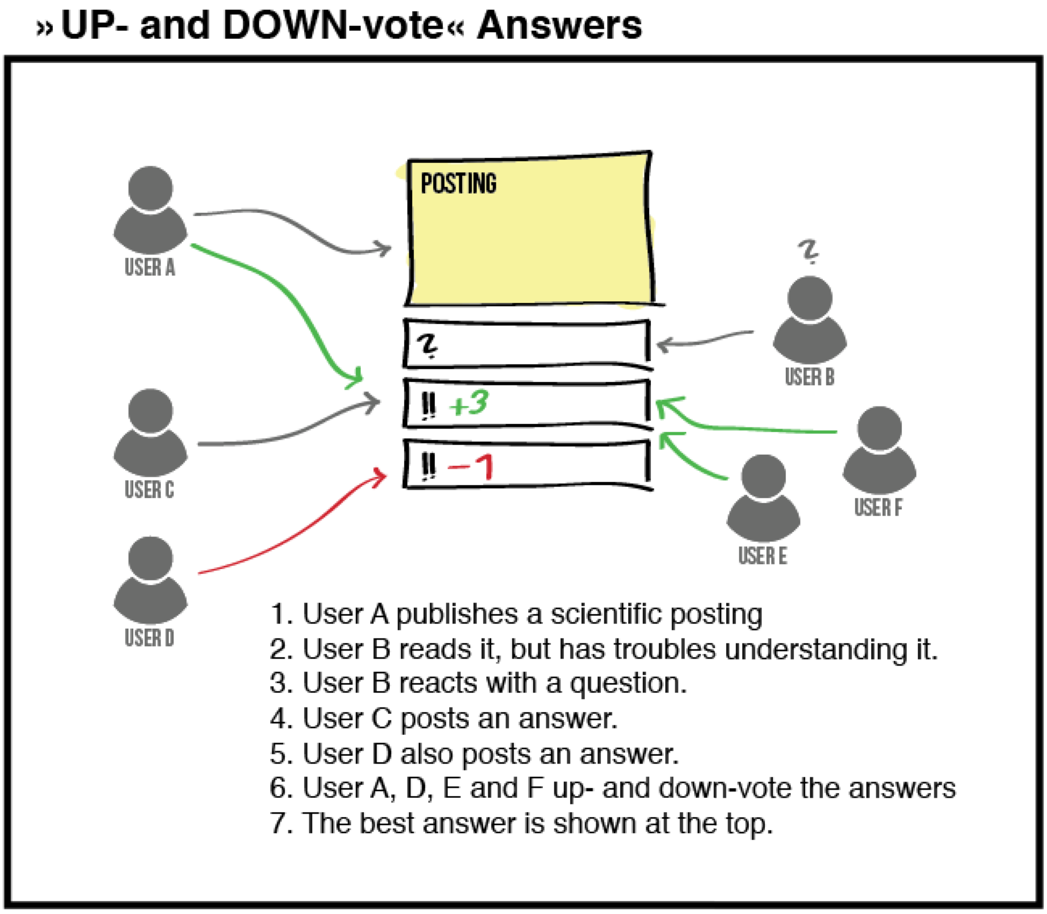

Figure 5.22: Users can up- and down-vote an answer.

Figure 5.22 shows the scenario of users rating answers to a posting. The collective feedback and reaction of all users result in a ranking. The most up-voted answer will be prominently displayed at the very top. Once an answer gets up-voted by others the author benefits through an increase of his/her personal PSCI.

5.3.6 Motivate Users to Participate & Incentive Mechanisms

In order to keep users active, there are several motivations to encourage participation. First, it is the individual user's task to care for personal reputation. An active contribution will lead to a higher PSCI and public recognition. Top scientists can attract the public's attention. As figure 5.23 shows, users with a high PSCI are highlighted at the top of the homepage.

So-called *Hot Questions* try to highlight most discussed content. These hot questions are

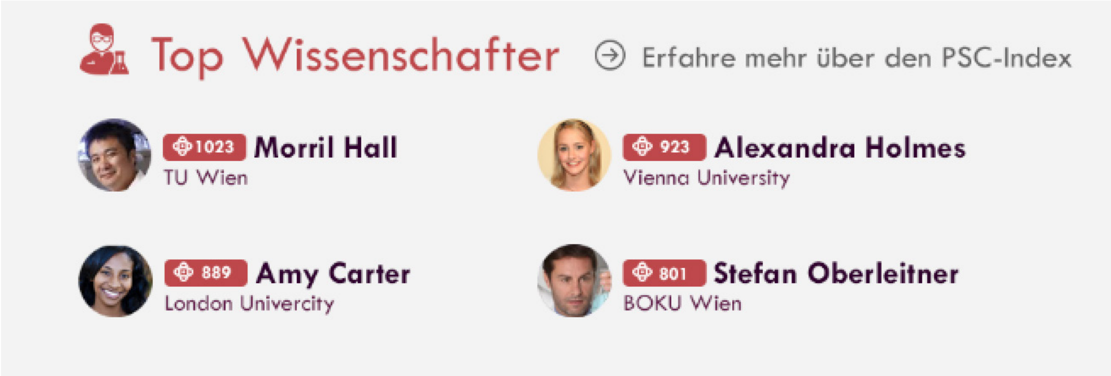

Figure 5.23: Users with highest PSCI are rewarded with a featured representation of their profile.

all labeled with different fields of knowledge that make it easy to categorise the questions. Bringing one's individual PSCI to the limit also includes discussing at the cutting-edge and being up-to-date. Quick (and correct) responses will result in an extra bonus for the ranking mechanism.

Based on previous activity, askScience can encourage users to contribute in their own field of expertise. Figure 5.24 shows how an individual motivation to help could look like. The platform can specifially ask users to help. This can be implemented in a section like *»Questions we think you can answer«* or *»Projects that need your help«*.

Figure 5.24: askScience suggests individual touch points to share expertise knowledge

askScience intentionally does not propose any registration barriers like Researchgate. It meets scientists and non-scientists on the same level. If a non-academic person can make a name for himself/herself, the public science contribution index - that acts as the community appreciation value - will prove the expertise.

5.3.7 Discussion

askScience represents an approach to science communication that builds on pro-active scientists' participation. At the same time there is no differentiation between scientists and non-scientists, leading to the possible phenomenon that a non-academic could outperform scientific experts. This might result in a reversal of roles.

A proposed index to really measure scientific contribution assumes that all science communication aspects are published via the platform introduced. This is not viable. In order to solve this problem, alternative altmetric approaches have to be considered.

This global challenge or wicked problem cannot be solved within a prototype developed within this design process, but askScience shows an example of building public appreciation. However, the idea to equate the expertise of scientists and non-academics is something we like in this approach and we pick up in the last prototype.

5.4 Prototype 4: Science Streams

5.4.1 Contextual Motivation

Understanding science and the interest in science does not require a scientific career path, as the Austrian education system shows. It involves a first academic experience when students graduate from a grammar school (*Allgemeinbildende Höhere Schule, AHS*) or a vocational high school (*Berufsbildende höhere Schule, BHS*). Based on the revision of the School Instruction Act (Schulunterrichtsgesetzt, SchUG, BGBI. no Nr.174/2012 as amended) [BGB12], the A-level (*Matura*) includes a so-called *Vorwissenschaftliche Arbeit (VWA)* (pre-scientific paper) at AHS or project work and diploma thesis at BHS.

Another programme by the *Federal Ministry of Science, Research and Economy* (http://www.en.bmwfw.gv.at) supports this early contact of pupils with science. The *Sparkling Science* initiative focuses on project cooperations of schools and universities. Since 2007, over 260 projects in the field of Citizen Science have been started and 187 of them have been finished (by April-2016) [Spa16].

These insights into scientific research offer great opportunities for pupils and allow them to understand the workflow and impact of science. The following prototype is an artefact of the explorative design process within this thesis and shows an example of how science communication can be used in this educational context.

5.4.2 System Design

Based on the insights of previous prototypes and the initial research, a new system design is set up to create a tool that supports both the communication within project teams and between project teams and the public.

Based on the example of *Sparkling Science* projects [Spa16], a typical project team consists of several students that are supervised by a teacher. This team is assigned to a scientific institution that involves the project team in a research project. In this project setting, a lot of artefacts like reports, results, insights, documentations and feedback are generated and represent valuable content for public science communication. The new concept focuses on these data and offers a tool to centrally collect and selectively publish the content. Therefore, we distinguish two scopes: the *project space* and the *public space*.

The **Project Space** offers a closed platform for schools and scientific institutions (e.g. university, research companies,..). It is considered to be a communication tool for project members, teachers and researchers. An instant communication tool (chat function) is combined with media collection tools (see *5.4.4 The Media Pool*). All artefacts produced in this project space are for internal use and are not published by default, ensuring that scientifically inexperienced scholars do not have to be afraid of publishing inaccurate content. The access to project teams is administrated by the teachers and researchers and requires verification.

On the contrary, the **Public Space** shows insights, outputs, results and documentation of the project to the public audience. Multiple *science streams* (see *5.4.5 Science Streams*) selectively document the project's progress. A preceding filter mechanism, an approval system by moderators and a *storifying* approach ensure the stream's content quality. The public space also includes interaction with non-project members. Everyone is encouraged to ask questions about the science that is done. These questions can be answered by the researchers or passed on to the scholars as new research challenges for them.

5.4.3 User Roles

Prototype 4 is a tool supporting cooperation on a project basis. Therefore, different user roles are identified and are visualised in the conceptual system draft (see figure *5.25*):

- **Scholar**
  A *scholar* is an undergraduate member of the research project. Within a project team a scholar contributes with his/her work and produces project related artefacts. Typical tasks in a scientific project could be data collection, data preparation, data verification or report generation and documentation. Scholars communicate with their teacher and associated researchers. All artefacts produced while communicating within the project or media data are collected centrally and can be used for public science communication.
- **Teacher**
  A *teacher* acts as a supervisor of the project within the school and is the first contact person for scholars when having administrative issues. The teacher ensures a working project team setting and steers the organisation along a desirable course.
- **Researcher**
  A *researcher* is a member of a scientific institution and focuses on the project's scientific approach and methodology. He/she communicates with the project members (scholars) and defines the tasks. Reviews, feedback about the work and project documentation are also included in a researcher's responsibility.
- **Moderator**
  A *moderator* can be a scholar, a teacher or a researcher and is responsible for the

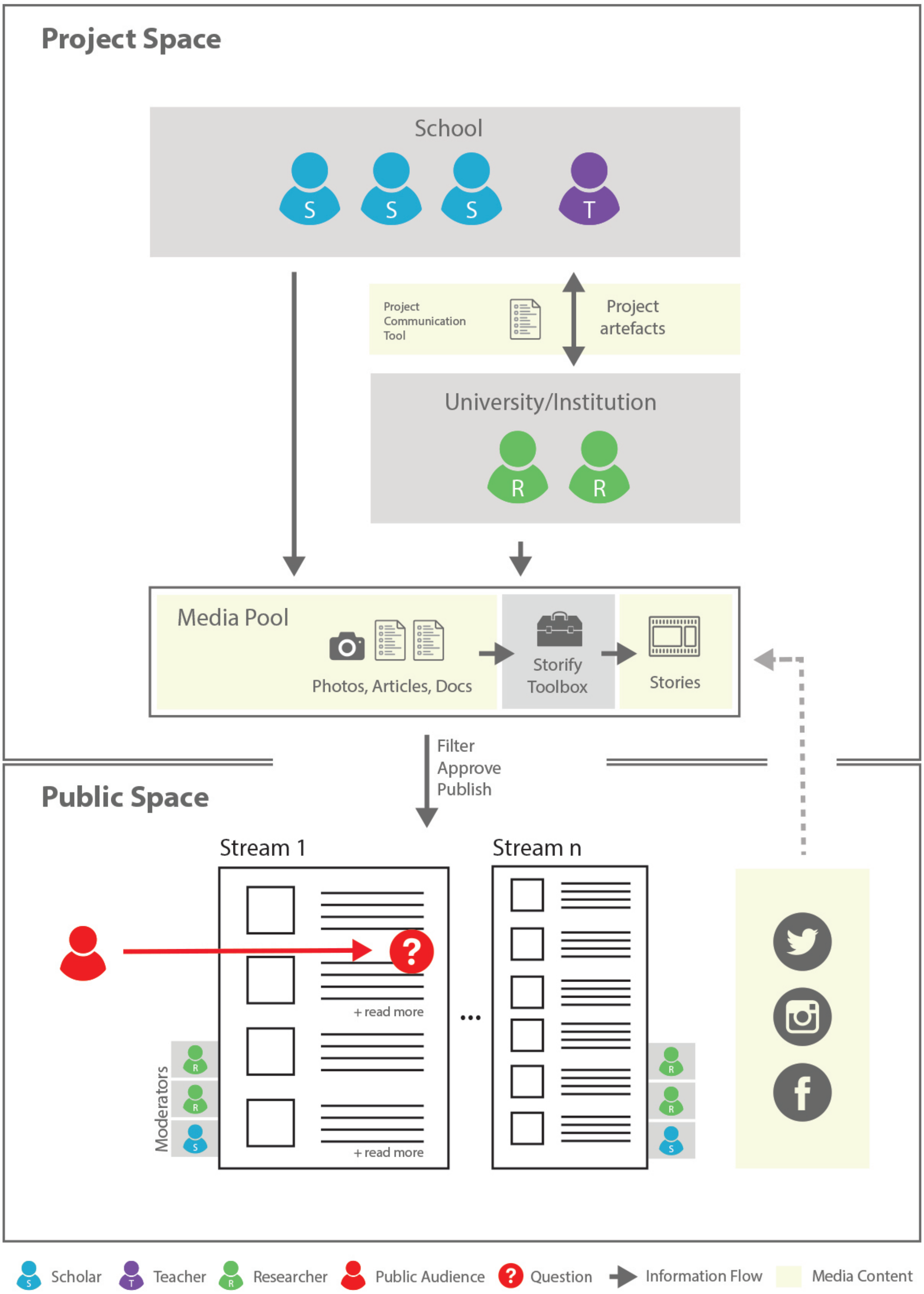

Figure 5.25: Conceptual sketch of system design of prototype 4.

generation of a science stream (see *5.4.5 Science Streams*). He/she refers to the content provided by all project members and collected in the media pool and filters, approves and publishes selected data in the science streams. A stream needs at least one moderator. A project member can be a moderator in several streams.

- **Public User**
  A *public user* can be any interested visitor on the website and represents the viewer of the science streams. Questions allow the public user to get in contact with the project teams and/or researchers.

5.4.4 The Media Pool

Working in a project generates a lot of data and artefacts that can be used to create reports, documentation and stories for public communication. However, the aspect of documentation often stands back while trying to reach the project goal. Therefore, all data that has been shared within the whole process is collected in a central *media pool* that is only accessible for internal project members in a first step. This closed pool of media data allows everyone to contribute and tries to maximise data collection without any filter mechanisms and quality checks for publication. The media pool is a protected cloud space to share and collect all project-related data across the school and university. It is the duty of the moderators to decide what media content is appropriate for public communication and what content does not leave the protected project space.

In this media pool, a so-called **Storify Toolbox** is attached and represents a toolkit of media processing applications. Project members can use this toolbox to create **stories** out of the media data collected. These stories can be picture slide shows, video sequences or multimedia presentations that can be published in different science streams. The Storify Toolbox has a modular design and may therefore be easily extended.

The media pool also includes external social media content. A Twitter, Facebook and Instagram interface enables users to import the content published on other social network platforms. These postings, tweets and images can be reused when creating stories and allow to extend the reach and interactivity of the media content.

The content that has been created at the hackathon demonstrates how the results of this storytelling approach could look like (see section *6.1.4 Alternative ways to communicate science*) and gives great examples of alternative ways to communicate science.

5.4.5 Science Streams

A *Science Stream* is the public representation of the project and selectively unites the media content produced. Science streams appear in the public space and can be accessed by every visitor without a registration process. The stream's content is moderated by one or many project members. These moderators are responsible for the channel's quality. Science streams include articles, photos, videos and other multimedia presentations that come out of the protected media pool. Each project team can have several project channels to individually customise the insight that a certain stream offers to the public. For example, a project team may decide to have different streams for different purposes:

- *'Stream #1: Project Overview'* acts as public representation for every interested person and enables a quick overview for initial visitors to get the general idea of the project. Only teachers and researchers are allowed to select the content displayed.
- *'Stream #2: Project Documentation'* is a detailed feed including all project steps for documentation purposes.
- *'Stream #3: Scientific Report'* shows all scientifically relevant information and focuses on the research approach. Only members of the research institution can moderate the content.
- *'Stream #4: Photo Impressions'* collects all photos taken by the scholars and project members. Everyone can contribute. An Instagram integration even includes postings on the social network.

5.4.6 Prototype mockups

Prototype 4 introduces a HTML mockup to demonstrate the concept of Science Streams. Figure 5.26 shows a single stream with different media elements and interaction possibilities. It includes a sequence of multimedia content. Each article and section has its own comments section that allows discussion and encourages people to join the public conversation. Detail pages extend the stream for more information. As each stream is assigned to a specific field of expertise (e.g. nature, physics, technology,..), every stream appears in a category-related colour. The example stream uses green as its main color as it is a stream in the field of nature. Referring to the previously described *conceptual system design* (see figure 5.25), the mockup implementation represents an artefact within the *public space* and is accessible for every interested user. Its content is moderated by assigned moderators and generated from the *media pool*.

Furthermore, the HTML prototype also includes a design draft for a *user dashboard*. This dashboard is placed in the *project space*. Project users and stream moderators use this dashboard to administrate their media content. It includes a comments overview including latest discussions. In addition, moderators can easily administrate newly published content in their different streams.

All streams can be easily extended by adding content from the *media pool*. The media pool includes all artefacts and stories that are produced during the project lifecycle. Figure 5.28 demonstrates an easy and *live* editing from a moderator's perspective.

5.4.7 Public Science Communication

The concept of Science Streams combines both citizen science aspects and science communication. Undergraduate scholars can contribute with their work in a research project and

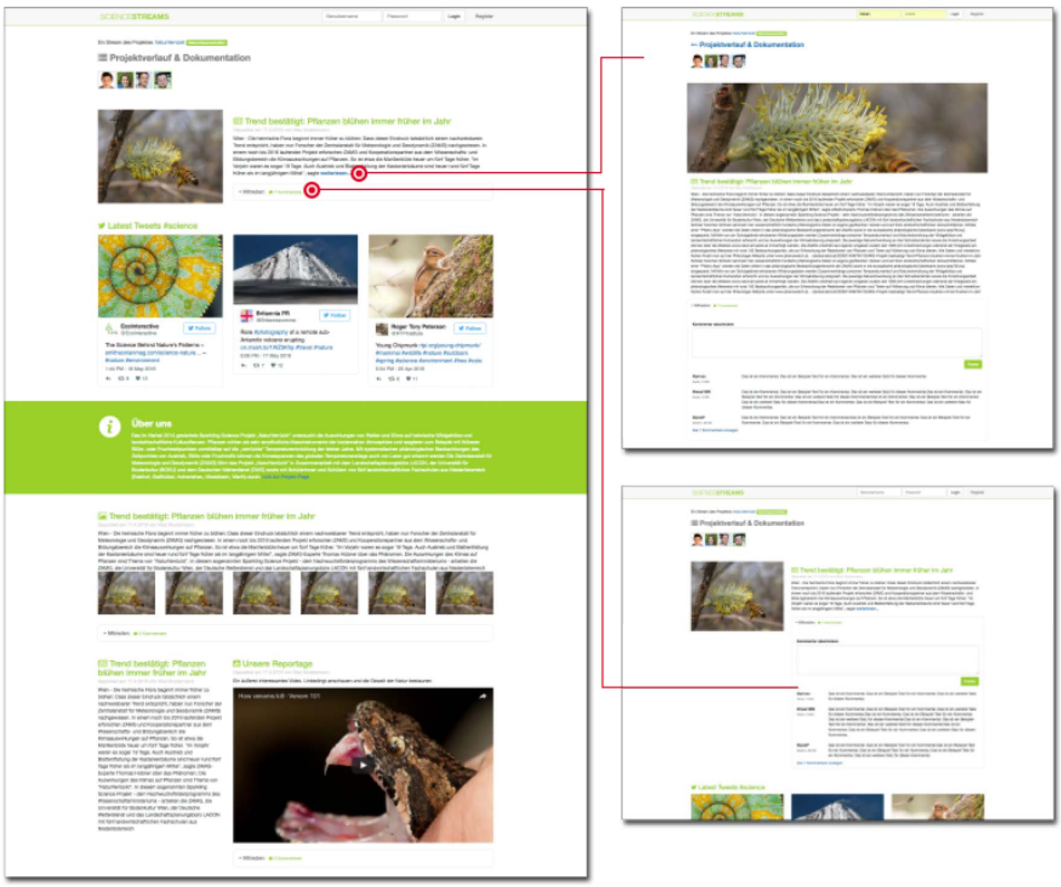

Figure 5.26: HTML prototype of a Science Stream with detail page and comments section.

media collection. Researchers cooperate with non-scientists and enable insights into the world of science. In addition, every interested visitor can get in contact with research projects by asking questions in the science streams. Every content includes a comment section where people can get in touch with the people responsible for the project and ask questions. These different comment sections are designed to specifically assign conversations to media artefacts that are produced within the project's progress.

Science Streams is a platform to communicate science projects. Different streams that can be created and published by the project members can address various kinds of target groups. This feature can be used to customise the project's outcome in order to make it fit the public's interest. Besides the projects' representation, Science Streams also allow experts to offer help in their area of expertise. The project labels and categories help users to find interesting discussions they can join. The community page connects (non-experts') projects with scientific discourses and enables direct communication.

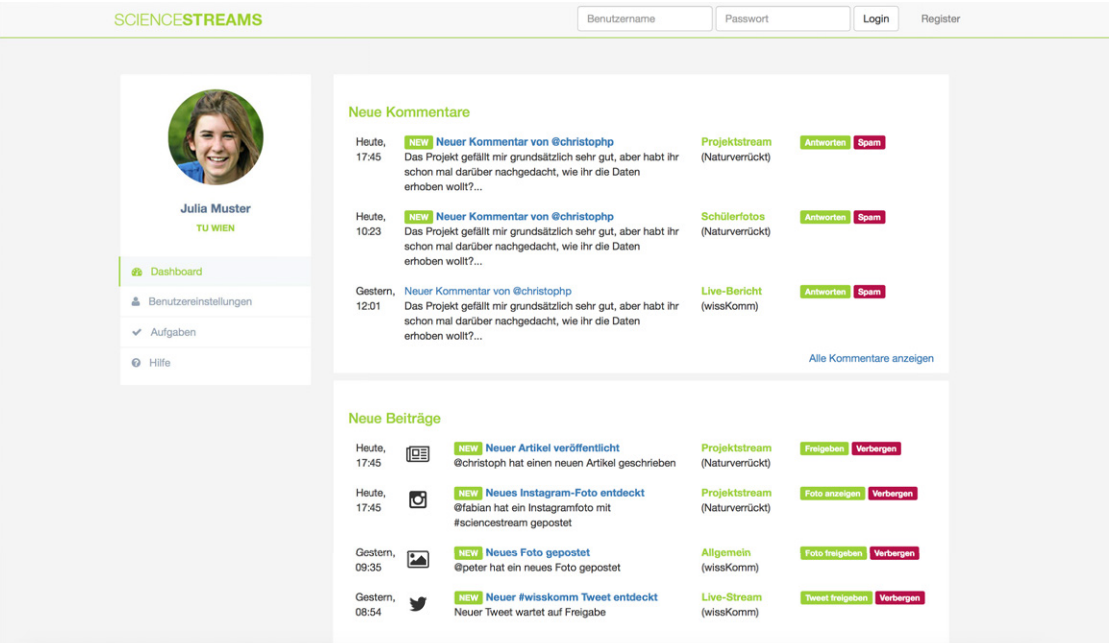

Figure 5.27: A proposed dashboard design for Science Streams

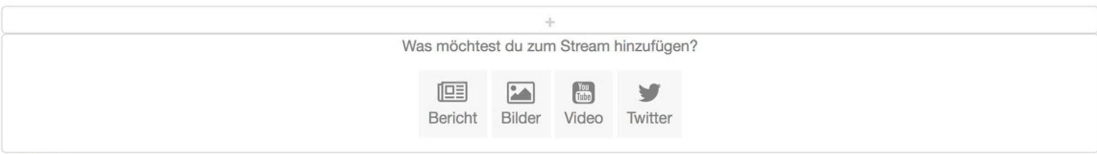

Figure 5.28: Live editing from a moderator's perspective at Science Streams.

CHAPTER 6

Evaluation

All prototypes proposed within the design process show different findings that have been gained through user feedback talks or field tests. The following chapter will focus on the evaluation of snap.science as this prototype was implemented as a high-fidelity prototype. A field test and a group discussion will then lead to the final discussion.

6.1 Field testing: Hackathon

Field testing and field research is a major part of classic qualitative research. *Oberservation* represents the common methodology to collect data. It is about trying to research the subject in a very natural setting without intervention of the research method. The goal is to gain insight, not to find an unrealistic and outside perspective [May02]. In line with this idea of qualitative research methodologies, the snap.science prototype has been field-tested at a hackathon concerned with new ways of science communication.

6.1.1 wisskomm - the hackathon

A *hackathon* is an event where different people meet for a limited time to create something. Originally, a hackathon was held to produce source code, as many software companies started these kinds of events. Today, the term *hackathon* is more diverse. Besides source code, specific applications of technology or new ways of using technology for special purposes are the benefits of hackathons. The scientific field has also started to follow the trend and started conducting such creative sessions [TKCH16].

Within the scope of a science communication project by the *Federal Ministry of Science, Research and Economy* (http://www.en.bmwfw.gv.at) in cooperation with the HCI Group of the *Institute for Design & Assessment of Technology* , TU Wien, a science communication hackathon called *wisskomm* was held in November 2015. 23 students and scholars, all considered to be *digital natives* [Pre01], met to find new ways of communicating scientific

Figure 6.1: Participants and mentors at wisskomm-hackathon.

topics. Professional marketing experts, science communicators, graphic and product designers helped the participants as mentors with their expertise.

Five groups of students chose a scientific, published paper and created a common understandable version of it. They were encouraged to use any kind of media they want. The results and alternative ways of science communication can be found in section *6.1.4 Alternative ways to communicate science*.

Science communication officers

Each team had to choose a person that was responsible for documentation and science communication within the hackathon. This person was called *science communication officer* and was introduced to the prototype platform of snap.science. Having registered, a project page of the group work was set up. During the whole hackathon, the science communication officers were encouraged to publish content (photos and text postings) about their project progress. Figure 6.2 shows some exemplary postings that were created and published via the mobile webpage.

This field test was used to collect usability data about the first prototype of snap.science. Feedback sessions and spontaneous interviews with the communication officers concerning usability and features were held all over the day. In order to focus on this user feedback a focus group session with these first users was followed. All feedback issues, findings and feature requests will be summarised in *6.1.4 Alternative ways to communicate science*.

6.1.2 Group Discussion

Qualitative Research is based on individuals' opinions and experiences. These subjective attitudes are often bound to social context, as Mayring [May02] says: Group interviews or group discussions are most qualified to collect public opinions and collective ideologies, because they are are even built in social structures.

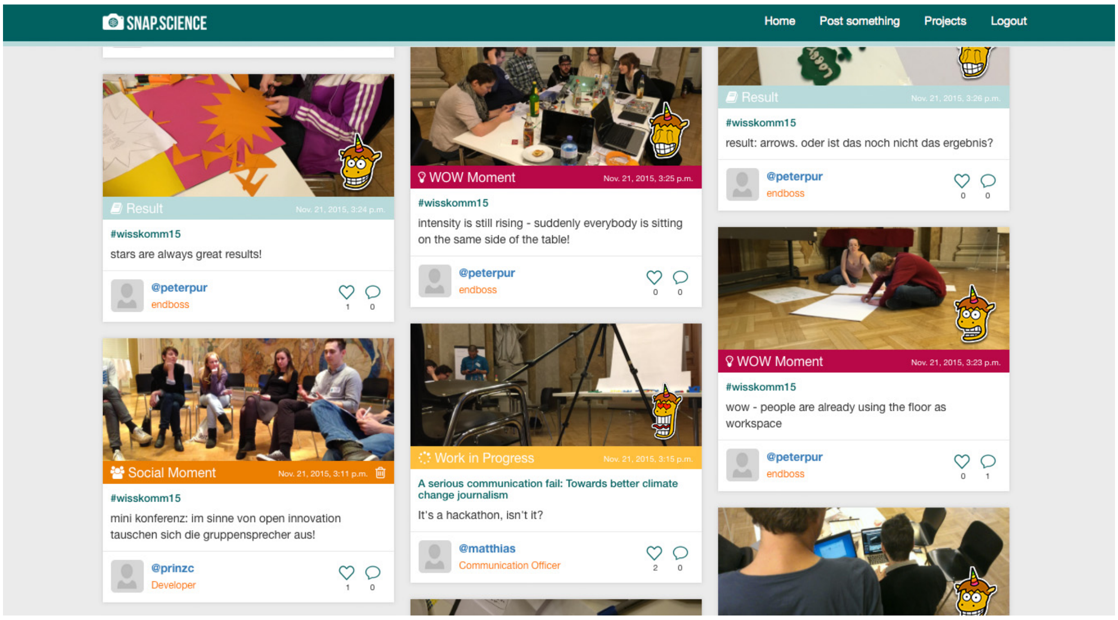

Figure 6.2: Postings on snap.science during the hackathon.

Figure 6.3: Group discussion with Natascha Machner, Matthias Wunsch, Sabrina Burtscher and (not on the picture) Christoph Prinz and Peter Purgathofer.

In a next step, all science communication officers of our field test at the hackathon were invited to join a group discussion for further evaluation and feedback. These people represent the first users of the implemented prototype of snap.science. In a 90 minutes workshop feedback was collected and new ideas and improvements were developed.

Based on observations and instant feedback at the hackathon, some questions have been defined to start the focus group discussion. These questions have been categorised into several sets of questions:

- **Storytelling as the concept of success for science communication**
  The prototype focuses on a storytelling approach. An automatically generated timeline made out of user postings tries to tell the story of a scientific project.
  - What is a good story?
  - How can scientists be encouraged to tell their stories?
  - What is needed to tell a good story? What kind of media?
  - Quality vs. quantity - What extent is needed to make a story attractive?
- **Scientists' obligation vs. the public's obligation**
  There has been an ongoing discussion at the hackathon whether it is the scientists' obligation to proactively communicate their scientific insights or not.
  - Is it a scientist's obligation to actively communicate the insights?
  - What personal motivations can speak in favour of a proactive science communication?
  - How can snap.science support researchers to actively communicate their research progress?
- **Expertise role and content**
  Some scientists might fear to lose their role of expertise when communicating their scientific work in public allowing anyone to join.
  - How can snap.science ensure the role of expertise?
  - Simplification of science vs. detailed and correct documentation? Where is the trade-off?
  - What is the scientist's benefit when explaining science to a public audience?
  - Science Communication and seriousness - Does science have to be boring? (stickers, memes,..)
- **Students as users**
  Besides researchers, students should be addressed as a target group.
  - How can students be motivated to join the platform?

- What content can students deliver?
- What kind of interaction/conservation do students want?
- What are the benefits for students to join?

These predefined questions have been used to initiate the discussion.

6.1.3 Evaluation Results

The collected feedback and user testing results have been combined and categorised into five different groups: *Feature Requests (F)*, *Platform Positioning (P)*, *Motivations (M)* and *Posting Categories (C)*. The following Tables will show these findings.

Table 6.1: snap.science findings: Feature Requests (R)

No.	**Description**
R1	Retrospective editing of postings and timeline
R2	Backdate postings
R3	Notification system on smartphone
R4	Individual placement of sticker
R5	Place stickers on others' postings
R6	Tag users in postings and comments (e.g. @prinzc)
R7	Limited access to projects. Not every user should be allowed to join a project.
R8	Categorisation of projects.
R9	Projects should have a place enabling a location-based search or "projects near you".
R10	Users should be able to follow places or institutions (e.g. follow TU Wien)
R11	Projects should be assigned to professional disciplines.
R12	Groups to find people and projects with same interests.
R13	Automatic Twitter or Facebook integration.

Several features (see table 6.1) were identified that have not been implemented in the first prototype version for the field test. A retrospective content manipulation and creation (*R1*, *R2*) would help users not to be disturbed by the system during work. A workshop participant said: *»I took a lot of pictures during the progress, but I wanted to post them afterwards.«* All test users mainly used the mobile version of the snap.science platform. Therefore, a notification system implemented as a mobile push-notification system should be offered (*R3)*.

R4 and *R5* talk about the stickers that can be placed on picture postings. All participants agree that they are a nice feature but suggest to make them more individually useable. This includes free positioning of the stickers, sticker reactions in comments, and putting stickers on others content. There was no indication that these stickers would put the seriousness of science at risk. However, *R7* addresses some concerns about the integrity of the platform. Users should not be able to join projects without any kind of approval system. User requests and manual approvals by project administrators would help not to lose control.

Furthermore, there were some feature requests about the projects' searchability and discoverabiltiy (*R8, R9, R10, R11*). Project categorisation, tags, or different disciplines (e.g. Physics, Medicine, Technology, Nature,...) would allow to filter projects. In addtion, *R12* also supports the wish to connect with like-minded people: The system cour, for example, be able to connect similar projects and people within a specific location (e.g. PhD students at TU Wien).

The next category of feedback findings deals with the strategic positioning and focus of the platform. Table 6.2 shows the findings related to this apsect.

Table 6.2: snap.science findings: Platform Positioning

No.	Description
P1	Better communication of platform's context
P2	Scientific competition
P3	Platform should focus on scientific interaction and communication

Talking about snap.science's strategic positioning and appearance, some issues were identified. First, the context has to be defined. Within the field test, it was not clear what kind of audience will receive the content published (*P1*). Questions like *»Who will read my postings?«, »Are there only students and scholars?«* arose and demonstrated that the context has not been clearly communicated. This phenomenon leads to a next point where group participants wished for more interactivity (*P3*). Referring to first users, the like-button and comments section have been under-represented. Better presentation of interaction and communication tools within the pjlatform would encourage communication. Last but not least, scientific competition (*P2*) has been mentioned, which will be discussed in more detail in section *7.2 Intellectual Property at Universities*. Early publications about and insights in scientific progress might endanger intellectual property and might hold researchers back from publishing everything on a platform like snap.science.

The attempt to build a social network always brings along the question of user motivation. The following table (see table 6.3) shows the evaluation findings.

Table 6.3: snap.science findings: User Motivation

No.	Description
U1	Project Documentation
U2	(User) Interaction as motivation
U3	Fun
U4	Peer Pressure
U5	Rewards and incentives for good work
U6	Open Innovation character

Snap.science has been introduced to the communication officers as a tool to document and communicate the projects' progress which has been the main reason of motivation, as the focus group found out (*U1*). Besides fun (*»Posting about our progress is fun.«- U3*), more user interaction and communication would be a good reason for users to (re-)use the platform (*U2, U4, P1*). Communicating with others is a way to bind users to a service. Statements like *»..because the others also use it«* emphasise this kind of peer pressure (*U4*).

U5 first introduces a new concept to the online platform. Users want rewards and incentives for their good work: *»One has to be rewarded, if he/she creates really good content«*. The ideas of the focus group include posting highlights (e.g. best posting of the month), honours for most active users or hall of fame concepts. Extraordinary work should be appreciated by the community or by scientists. All these possible motivations help to encourage users to join and publish their work on the community platform. Publishing findings and results should be in the interest of every scientist (*U6*).

Table 6.4: snap.science findings: Posting Categories

No.	Description
C1	*Challenge* has not been clear
C2	All types are too retrospective
C3	When do you use a milestone?
C4	Introduce a category for the "Follower Power"

Snap.science's post creator offers six different types of postings: WOW Moment, Social Moment, Work in Progress, Challenge, Result and Milestone. The focus group reported a problem of comprehension about the *challenge*. It was not clear whether this type represents a challenge within a project team or the it is meant to be a challenge for someone else (challenging task versus challenge for others - *C1*). An alternative suggestion was *Obstacle*, which would communicate a clearer message. *Milestones* also were not clear to every test user: There were different understandings about the time when a milestone should be used. Some used a milestone when achieving a goal, while others used the milestone when setting the goal (*C3*).

Next, the focus group criticised the retrospective categorisation. All types deal with events that have been finished and document a prior task. A category saying *»What's next«* would be a good opportunity to talk about further steps and planned tasks *emphC2).Thiskindofproactivepostingtypealsoinclu*
thefollower power.Itincludessituationsinwhichtheprojectteamwantstoaskquestionstothepublicaudience.Feed

6.1.4 Alternative ways to communicate science

Five groups of scholars and students of all different kinds of studies made use of various storytelling approaches to communicate traditional paper publications. The outcome was a great load of creativity and alternative multimedia content [1].

A group of three students created a stop-motion cartoon that explains a mathematical model of a zombie infection by Philip Munz *et al*[MHIS09]. They created simple pen & paper sketches to demonstrate four different simulations and combined these graphics with

[1] All results can be found on www.wisskomm.at

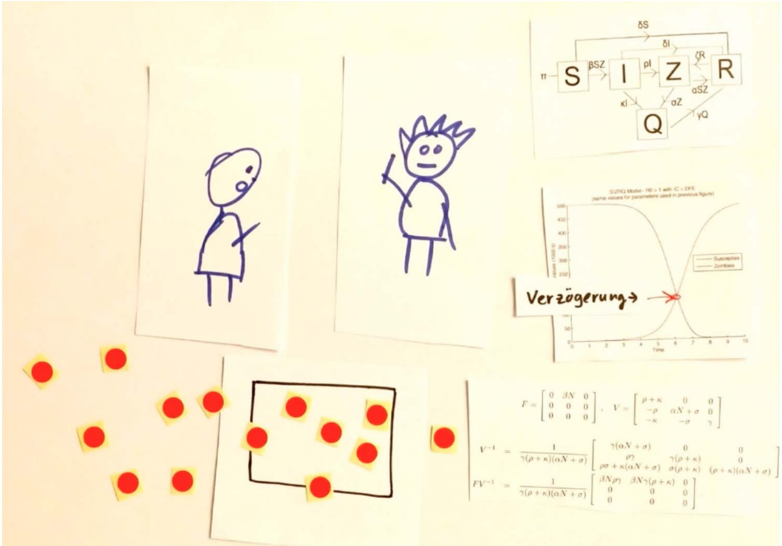

Figure 6.4: A screenshot of a stop motion cartoon, drawn and filmed by Alexander Bayer, Natascha Machner and Christian Steindl

annotations and pictures (of mathematical formulas) on a white sheet of paper. A series of photographs of this settings builds the foundation of this stop-motion video. See figure 7.4 for a screenshot of the final result.

Figure 6.5: A screenshot of the video with subtitles.

Another group of three participants had a look at the effects of pain to the verbal manner of expression. They chose the approach of browsing the web to find video content in this field and created a subtitled video showing an experiment and explaining the content of the scientific paper. This video was based on a publication by Richard Stephens *et al* [SAK09]. See figure 7.5 to find a screenshot of Jakob Bal's, Thomas Cap's and Daniel Hupfer's work.

Figure 6.6: Stop-motion video using play-doh.

In addition, a group of five students also created a stop-motion video to address the issue that journalism has failed to talk about climate science in order to inform the public audience. This project group worked on the foundation of a paper by Steve McIlwaine [McI00]. In contrast to the previous group, they decided to use play-doh instead of sketches to express their issue in a three-dimensional way. They created a nice setup to stage their story with tangible objects made out of play-doh. A screenshot of the final video can be found in figure 7.6. The video has been produced by Damir Dizdarevic, Anna Malis, Gerald Reitschmied, Markus Wallinger and Matthias Wunsch.

Next, a group of Cornelia Hasil, Daniel Dudo, Florian Schuster, Larissa Kalbhenn, Rene Koller, Robert Rainer, Sabrina Burtscher and Guenther Khyo worked with a paper about bad interface design by Donald Gentner et al [GG90]. It includes the fact that software engineers understand the theoretical mechanism in a system and therefore tend to build the user interfaces upon this abstract knowledge. The project group chose a different approach. They created an Instagram account[2] that interactively shows why good engineers sometimes create bad interfaces. The arrangement of Instagram pictures has been chosen wisely to communicate a story on an existing social media platform that is not considered to be a science communication channel in general. The reach of a new audience was the motivation of this group. See figure 6.7 to find a screenshot of the group's result.

Last but not least, one group chose the topic of Murphy's Law and influencing constants. This paper has been published by R. Matthews [Mat95]. Kathrin Conrad, Matthias Steinboeck, Maximilian Stoiber and Gabriele Urban composed and recorded a song about the paper's

[2] http://instagram.com/insta_science_comm/

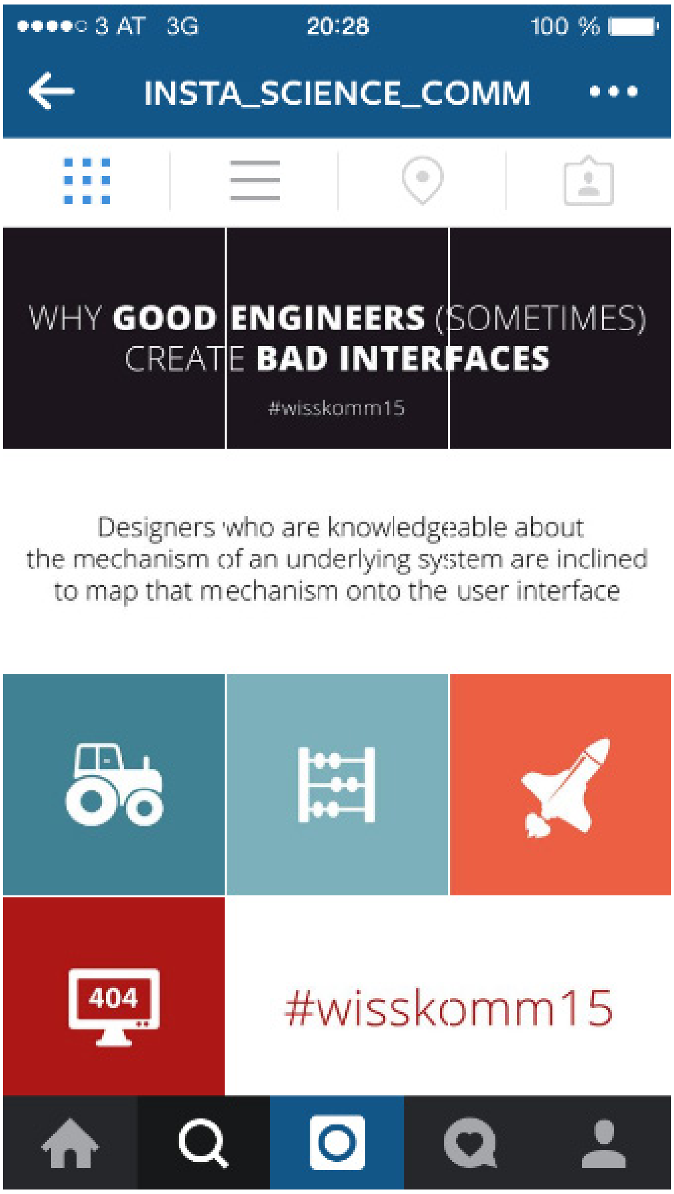

Figure 6.7: An Instagram account to communicate science.

content. In addition, they captured a live painting session visually explaining the song. This musical performance combined with amazing sketching skills resulted in an interesting way of communicating science. See figure 7.8 to find a screenshot of the final video version.

These outcome representations of the hackathon demonstrate the huge variety of media usage in the field of science communication. Videos, stop-motion animations with sketches or other material (like play-doh), novel use of existing social media platforms or music can

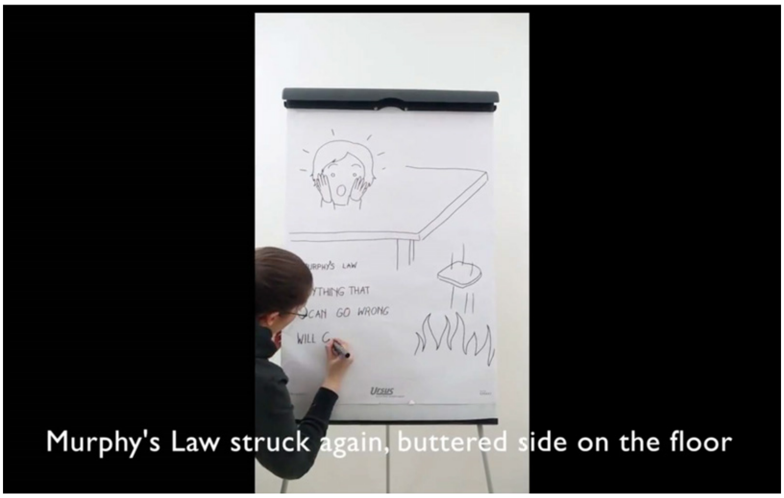

Figure 6.8: Live-Painting and singing as an alternative way to present science.

be easily used to spread scientific results. The potential virality and easy access to public audience is given.

CHAPTER 7

Summary & Discussion

7.1 Prototype Summary and Findings

The explorative design process to tackle the wicked problem of science communication started with a first prototype called *inLab*. It has been influenced by general motivations of citizen science. Common design patterns of successful crowdsourcing platforms were applied to a more scientific context (e.g. infinity scrolling pages). However, we figured out that this approach was too broad and did not put the entire focus on communicating science. In addition, the researchers' encouragement to pro-actively participate was not given.

This led to a implemented high-fidelity prototype that tried to generate insights into a scientific life. Snap.science was implemented as an online platform to share everyday moments. Different posting categories tried to highlight the diversity of science. Evaluation also showed that incentive mechanisms are crucial when designing a new social network. Users want to be rewarded in any way whenever they provide good content. In addition, a field test at a hackathon revealed users' needs and desires. Mobile accessibility, a clear communication of the platform's positioning and audience, as well as a feature to push good content were some of the main findings.

This kind of incentive mechanism got picked up in the third prototype called Science Streams. An online platform connected non-scientists and scientists to share their knowledge. An exchange of questions and answers was the main idea. People could ask any kind of scientific question in any field of expertise. An index - expressing the public science contribution within the platform - should reward the user's pro-active participation. This metric had a major drawback: Introducing a new index to quantify scientific output is not doable with a simple proposed platform as this would need every scientist to join the community.

Finally, we tried to start tackling the *wicked* problem at a smaller scale. A defined context - pre-scientific works within the Austrian school system - laid the foundation for prototype 4: Science Streams. A clear system design and defined stakeholders allowed us to propose a system where science communication can be applied to a specific target group, namely scholars.

7.2 Intellectual Property at Universities

Throughout the whole investigations of this design process, the issue of *»Intellectual Property«* appeared several times. Critics and sceptics do not support the idea of open innovation and open science as they fear that intellectual property (and the right to claim one's invention) might get lost. The following paragraph will deal with this discussion:

Innovative technologies and latest inventions go hand in hand with intellectual property management. Despite the great benefit of open innovation, universities increasingly shelter their technological findings, as Mario Cervantes [Cer15] summarises. In 1980, a policy change in the United States, the so-called *Bayh-Dole Act*, first allowed universities to patent their inventions that have been funded by public support. The - as we now see - kind of naive idea was that this approach should encourage and boost the knowledge transfer from an academic setting to industry. Unfortunately, instead of booming research the effects have led to another point, as Mike Masnick [Mas13] claims: It is obvious that once you protect your findings with a patent you try to keep up the protection. This leads to a decrease in communication and exchange with other researchers that is very important for scientific progress. Second, following Masnick, the Bayh-Dole-Act triggered the vision of universities to make money out of the patents. *Technology Transfer Offices* have become the way to deal with this opportunity and universities started to sell as many licences as possible. As a result, less scientific findings got transferred to the real market then they expected.

Unfortunately, this is not the end of what Masnick critically calls a *dismal failure* [Mas13]. With very limited exceptional universities like Stanford or MIT, technology transfer offices are not able to fund their very own staff. A report by Brookings Institution[Val13] supports this attitude:

> *»Using tech transfer office expenses information, Valdivia estimates that 130 universities did not generate enough licensing income in 2012 to cover the wages of their technology transfer staff and the legal costs for the patents they file.«([Val13])*

The controversy demonstrated emphasises the urgent need of a required change in public awareness of open innovation.

7.3 Final findings

As the previous section shows, innovation is not about putting a shelter around individual findings to make money. Innovation is about communicating with each other, learning from everyone and sharing with everybody - without exclusion of non-scientists. It includes a dialog between scientific experts and citizens based on an equal footing. This thesis explored possible opportunities to connect researchers and interested people with the help of a social media platform that could be a first step to open the gates to the shelter.

The hackathon, with all the great and inspiring results, shows the amazing potential of how new perspectives from others can increase the value and perception of science. Researchers are supposed to work with high attention to detail and apply latest standards of knowledge to extend their expertise and to generate innovation in the interest of everyone. At the same time, it is very important not to see literature and scientific publications as the end of knowledge. There is precious expertise and experience in any field out in the world, as many citizen science projects demonstrate. The goal is to find this treasure and use it in a common interest.

An appropriate attempt to approach a solution to this wicked problem of science communication might be *participation*. Participation does not mean to apply techniques of public relations to stage science in a specific spotlight. It is something that happens voluntarily. If we can manage to achieve a way of science communication to awake people's interest rather then pursuing them to join, we would have achieved great success. Scientists do not lose their importance at all, but today - with the introduction of a digital world - their role is changing.

List of Figures

Bibliography

[Aca16] Academia.edu. About Academia.edu. https://www.academia.edu/about, 2016. Accessed: 2016-05-27.

[ACHVH09] S. Alonso, F.J. Cabrerizo, E. Herrera-Viedma, and F. Herrera. h-index: A review focused in its variants, computation and standardization for different scientific fields. *Journal of Informetrics*, 3(4):273 – 289, 2009.

[AF14] H Alhoori and R Furuta. Do altmetrics follow the crowd or does the crowd follow altmetrics? *IEEE/ACM Joint Conference on Digital Libraries*, pages 375–378, 2014.

[AGP13] Valerio Arnaboldi, Andrea Guazzini, and Andrea Passarella. Egocentric online social networks: Analysis of key features and prediction of tie strength in facebook. *Computer Communications*, 36, 2013.

[AHK08] Thomas R Anderson, Robin K S Hankin, and Peter D Killworth. Beyond the Durfee square: Enhancing the h-index to score total publication output. *Scientometrics*, 76(3):577–588, 2008.

[Ale64] C. Alexander. *Notes on the synthesis of form*. Harvard Paperback. Harvard University Press, 1964.

[BBS13] A. Begel, J. Bosch, and M. A. Storey. Social networking meets software development: Perspectives from github, msdn, stack exchange, and topcoder. *IEEE Software*, 30(1):52–66, Jan 2013.

[BG13] Holly M Bik and Miriam C Goldstein. An Introduction to Social Media for Scientists. *PLOS Biol*, 11(4):e1001535, April 2013.

[BGB12] BGBl. Bundesgesetzblatt II für die Republik Österreich, 174. Verordnung - Prüfungsordnung AHS, Teil 2. https://www.bmbf.gv.at/schulen/recht/erk/schug_nov_2010_19465.pdf, 2012. Accessed: 2016-04-06.

[BLW+04] Gerard Beenen, Kimberly Ling, Xiaoqing Wang, Klarissa Chang, Dan Frankowski, Paul Resnick, and Robert E. Kraut. Using social psychology to motivate contributions to online communities. In *Proceedings of the 2004 ACM Conference* on *Computer Supported Cooperative Work*, CSCW '04, pages 212–221, New York, NY, USA, 2004. ACM.

[BOS03] T. W. Burns, D. J. O'Connor, and S. M. Stocklmayer. Science communication: A contemporary definition. *Public Understanding of Science*, 12(2):183–202, 2003.

[BPBE16] Rick Bonney, Tina B Phillips, Heidi L Ballard, and Jody W Enck. Can citizen science enhance public understanding of science? *Public Understanding of Science*, 25(1):2–16, January 2016.

[BSP+14] Rick Bonney, Jennifer L Shirk, Tina B Phillips, Andrea Wiggins, Heidi L Ballard, Abraham J Miller-Rushing, and Julia K Parrish. Next Steps for Citizen Science. *Science*, 343(6178):1436–1437, March 2014.

[Buc09] Buchanan, Richard. Thinking about Design: An Historical Perspective. In *Philosophy of Technology and Engineering Sciences*, pages 409–453. Elsevier, 2009.

[Bux07] Bill Buxton. *Sketching User Experiences: Getting the Design Right and the Right Design*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 2007.

[CCL12] Chia-Shen Chen, Shih-Feng Chang, and Chih-Hsing Liu. Understanding Knowledge-Sharing Motivation, Incentive Mechanisms, and Satisfaction in Virtual Communities. *Social Behavior and Personality: an international journal*, 40(4):639–647, May 2012.

[Cer15] Mario Cervantes. Academic Patenting: How universities and public research organizations are using their intellectual property to boost research and spur innovative start-ups. `http://www.wipo.int/sme/en/documents/academic_patenting.htm`, 2015. Accessed: 2016-05-11.

[Che03] H.W. Chesbrough. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Harvard Business School Press, 2003.

[Che06] H.W. Chesbrough. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Harvard Business School Press, 2006.

[Cop95] Nicolaus Copernicus. 1543. de revolutionibus orbium coelestium. *Trans. AM Duncan*, 1995.

[Cor16] Cornell lab of ornithology. `http://www.birds.cornell.edu/Page.aspx?pid=1478`, 2016. Accessed: 2016-03-08.

[Cri92] Francis Crick. 4 - the impact of linus pauling on molecular biology: A reminiscence. In Ahmed Zewail, editor, *The Chemical Bond*, pages 87 – 98. Academic Press, San Diego, 1992.

[dja16] Django Framework. https://www.djangoproject.com, 2016. Accessed: 2016-04-13.

[DKND11] Sebastian Deterding, Rilla Khaled, Lennart Nacke, and Dan Dixon. Gamification: Toward a definition. In *CHI 2011 Gamification Workshop Proceedings*, Vancouver, BC, Canada, 2011.

[DMB16] Megan Davies, Josephine K. Musango, and Alan C. Brent. A systems approach to understanding the effect of facebook use on the quality of interpersonal communication. *Technology in Society*, 44:55 – 65, 2016.

[dVCG93] M.J. de Vries, N. Cross, and D.P. Grant. *Design Methodology and Relationships with Science*. Nato Science Series D:. Springer Netherlands, 1993.

[Egg06] Leo Egghe. Theory and practise of the g-index. *Scientometrics*, 69(1):131–152, 2006.

[Fac16] Facebook. Facebook Stats. http://newsroom.fb.com/company-info/, 2016. Accessed: 2016-05-27.

[FDT13] Erika Faernstrand Damsgaard and Marie C. Thursby. University entrepreneurship and professor privilege. *Industrial and Corporate Change*, 22(1):183–218, 2013.

[Ger90] John S. Gero. Design prototypes: A knowledge representation schema for design. *AI Mag.*, 11(4):26–36, October 1990.

[GG90] Donald R. Gentner and Jonathan Grudin. Why good engineers (sometimes) create bad interfaces. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '90, pages 277–282, New York, NY, USA, 1990. ACM.

[GMV+01] Jim Greer, Gordon Mccalla, Julita Vassileva, Ralph Deters, Susan Bull, and Lori Kettel. Lessons learned in deploying a multi-agent learning support system: The i-help experience. In *Proceedings International AI and Education Conference AIED 2001*, 2001.

[Goo16] Google answers. http://answers.google.com/answers/, 2016. Accessed: 2016-01-20.

[GWW11] Feng Gu and Gunilla Widén-Wulff. Scholarly communication and possible changes in the context of social media: A Finnish case study. *The Electronic Library ()*, 29(6):762–776, 2011.

[Han85] T.L. Hankins. *Science and the Enlightenment*. Cambridge Studies in the History of Science. Cambridge University Press, 1985.

[Hir05] J. E. Hirsch. An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences of the United States of America*, 102(46):16569–16572, 2005.

[Hir09] J E Hirsch. An index to quantify an individual's scientific research output that takes into account the effect of multiple coauthorship. *arXiv.org*, November 2009.

[Irw95] A. Irwin. *Citizen Science: A Study of People, Expertise and Sustainable Development*. Citizen Science: A Study of People, Expertise and Sustainable Development. Routledge, 1995.

[JDHL15] Wei Jeng, Spencer DesAutels, Daqing He, and Lei Li. Information Exchange on an Academic Social Networking Site: A Multi-discipline Comparison on ResearchGate Q&A. *CoRR abs/1511.03597*, 2015.

[JHJ15] Wei Jeng, Daqing He, and Jiepu Jiang. User participation in an academic social networking service: A survey of open group users on Mendeley. *JASIST ()*, 66(5):890–904, 2015.

[Kac15] Lisa C Kaczmarczyk. Do you speak #scicomm? *Inroads*, 6(2):31–32, 2015.

[KLR+11] Peter Kraker, Derick Leony, Wolfgang Reinhardt, Gü, and Nter Beham. The case for an open science in technology enhanced learning. *International Journal of Technology Enhanced Learning*, 3(6):643+, 2011.

[KO10] Donald Kennedy and Geneva Overholser. Your Congress - Your Health: Poll. *American Academy of Arts & Sciences, Cambridge*, 2010.

[Lim15] Sun Sun Lim. On Stickers and Communicative Fluidity in Social Media. *Social Media + Society*, 1(1):2056305115578137, April 2015.

[LK14] Amy Luers and David Kroodsma. Science Communication in the Post-Expert Digital Age. *Eos, Transactions American Geophysical Union*, 95(24):203–204, June 2014.

[LSY+14] Xuan Liang, Leona Yi-Fan Su, Sara K Yeo, Dietram A Scheufele, Dominique Brossard, Michael Xenos, Paul Nealey, and Elizabeth A Corley. Building Buzz (Scientists) Communicating Science in New Media Environments. *Journalism & Mass Communication Quarterly*, 91(4):772–791, December 2014.

[Mas13] Mike Masnick. Patenting University Research Has Been A Dismal Failure, Enabling Patent Trolling., It's Time To Stop. `https://www.techdirt.com/articles/20131122/01322825335/patenting-university-research-has-been-dismal-failure-enabling-pa` `shtml`, 2013. Published: 2013-12-02, Accessed: 2016-05-11.

[Mat95] R A J Matthews. Tumbling toast, murphy's law and the fundamental constants. *European Journal of Physics*, 16(4):172, 1995.

[May02] Philipp Mayring. *Einfuehrung in die qualitative Sozialforschung: Eine Anleitung zu qualitativem Denken*. Beltz, 5. aufl. edition, 2002.

[McI00] Steve McIlwaine. Journalism, climate science and the public: Towards better practices. *International Journal of Media & Cultural Politics*, 9(1):47–58, 2013-03-01T00:00:00.

[MHIS09] Philip Munz, Ioan Hudea, Joe Imad, and Robert J. Smith. When zombies attack!: Mathematical modelling of an outbreak of zombie infection. In *In J.M. Tchuenche and C. Chiyaka, editors, Infectious Disease Modelling Research Progress*, pages 133–150. Nova Science, 2009.

[Mit15] Ronnie Mitra. Rapido: A Sketching Tool for Web API Designers. *WWW ()*, pages 1509–1514, 2015.

[NH12] Ashwini Nadkarni and Stefan G. Hofmann. Why do people use facebook? *Personality and Individual Differences*, 52(3):243 – 249, 2012.

[NR11] David Nicholas and Ian Rowlands. Social media use in the research workflow. *Inf. Services and Use ()*, 31(1-2):61–83, 2011.

[NVP+16] Yuri Niyazov, Carl Vogel, Richard Price, Ben Lund, David Judd, Adnan Akil, Michael Mortonson, Josh Schwartzman, and Max Shron. Open access meets discoverability: Citations to articles posted to academia.edu. *PLoS ONE*, 11(2):1–23, 02 2016.

[oO96] Cornell University. Laboratory of Ornithology. *Living Bird*. Number Bd. 15-17. Cornell Laboratory of Ornithology, 1996.

[ope16] openscienceASAP. What is Open Science? `http://openscienceasap.org/open-science/`, 2016. Accessed: 2016-05-03.

[Pil15] Ola Pilerot. Information sharing in the field of design research. *Inf. Res. (IRES) 20(1)*, 2015.

[PKCP15] Nancy Pontika, Petr Knoth, Matteo Cancellieri, and Samuel Pearce. Fostering open science to research using a taxonomy and an elearning portal. In *iKnow: 15th International Conference on Knowledge Technologies and Data Driven Business*, 2015.

[Pre01] Marc Prensky. Digital natives, digital immigrants part 1. *On the Horizon*, 9(5):1–6, 2001.

[PTGN10] J. Priem, D. Taraborelli, P. Groth, and C. Neylon. Altmetrics: a manifesto, 2010.

[Pun05] K.F. Punch. *Introduction to Social Research: Quantitative and Qualitative Approaches*. Essential Resource Books for Social Research. SAGE Publications, 2005.

[Res10] Research!America. Your Congress - Your Health: Poll. *Charlton Research Company for Research!America*, 2010.

[Res16] ResearchGate. Researchgate. `http://www.researchgate.net`, 2016. Accessed: 2016-03-10.

[RHR16] Jonathan C Roberts, Chris Headleand, and Panagiotis D Ritsos. Sketching Designs Using the Five Design-Sheet Methodology. *IEEE Trans. Vis. Comput. Graph. ()*, 22(1):419–428, 2016.

[RW73] Horst W. J. Rittel and Melvin M. Webber. Dilemmas in a general theory of planning. *Policy Sciences*, 4(2):155–169, 1973.

[Rya15] Cami Ryan. Storytelling and science communcation. `https://doccamiryan.wordpress.com/2015/06/23/storytelling-and-science-communication/`, 2015. Published: 2015-06-23, Accessed: 2016-01-20.

[SAK09] Richard Stephens, John Atkins, and Andrew Kingston. Swearing as a response to pain : NeuroReport. *Neuroreport*, June 2009.

[Sim96] H.A. Simon. *The Sciences of the Artificial*. MIT Press, 1996.

[Soc85] Royal Society. The Public Understanding of Science. *Report of a Royal Society of London ad hoc Croup endorsed by the council of the Royal Society*, 1985.

[Spa16] Sparkling Science. Sparkling Science. `https://www.sparklingscience.at/en`, 2016. Accessed: 2016-04-06.

[Sta16] StackExchange. 2015 Stack Exchange Network Statistics . `https://stackexchange.com/about`, 2016. Accessed: 2016-05-27.

[Sto09] Victoria Stodden. The legal framework for reproducible scientific research: Licensing and copyright. *Computing in Science and Engineering*, 11(1):35–40, 2009.

[SW08] B.A. Somervill and M. Weatherly. *Nicolaus Copernicus: Father of Modern Astronomy*. Signature Lives. Compass Point Books, 2008.

[TK14] Mike Thelwall and Kayvan Kousha. Academia.edu: Social network or Academic Network? *JASIST ()*, 65(4):721–731, 2014.

[TK15] Mike Thelwall and Kayvan Kousha. ResearchGate: Disseminating, communicating, and measuring Scholarship? *JASIST ()*, 66(5):876–889, 2015.

[TKCH16] Erik H Trainer, Arun Kalyanasundaram, Chalalai Chaihirunkarn, and James D Herbsleb. How to Hackathon: Socio-technical Tradeoffs in Brief, Intensive Collocation. *CSCW*, pages 1116–1128, 2016.

[Tur36] Alan Mathison Turing. On computable numbers, with an application to the entscheidungsproblem. *J. of Math*, 58:345–363, 1936.

[Val13] Walter D Valdivia. University Start-Ups: Critical for Improving Technology Transfer. *Brookings Institiute - Center for Technology Innovation*, 2013.

[Vas12] Julita Vassileva. Motivating participation in social computing applications: a user modeling perspective. *User Modeling and User-Adapted Interaction*, 22(1-2):177–201, March 2012.

[VSK96] Robert A. Virzi, Jeffrey L. Sokolov, and Demetrios Karis. Usability problem identification using both low- and high-fidelity prototypes. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '96, pages 236–243, New York, NY, USA, 1996. ACM.

[Wak03] Ron Wakkary. Pete and repeat were sitting on a fence: iteration, interactive cognition and an interactive design method. *Proceedings of Fifth International Consciousness Reframed (2003), Caerleon, Wales, UK, Intellect Press*, 2003.

[Wen07] Michael C Wendl. H-index: however ranked, citations need context. *Nature*, 449(7161):403–403, September 2007.

[Wil12] Christie Wilcox. Guest Editorial: It's Time To e-Volve: Taking Responsibility for Science Communication in a Digital Age. *The Biological Bulletin*, 222(2):85–87, April 2012.

[WTL02] Miriam Walker, Leila Takayama, and James A. Landay. High-fidelity or low-fidelity, paper or computer? choosing attributes when testing web prototypes. In *PROC. HUMAN FACTORS AND ERGONOMICS SOCIETY 46TH ANNUAL MEETING*, pages 661–665, 2002.

[YAC+14] Jason C Yip, June Ahn, Tamara L Clegg, Elizabeth M Bonsignore, Daniel Pauw, and Michael Gubbels. "It helped me do my science.": a case of designing social media technologies for children in science learning. *IDC*, pages 155–164, 2014.

[Zak15] Paul Zak. Why Inspiring Stories Make Us React: The Neuroscience of Narrative. *Cerebrum: the Dana Forum on Brain Science*, February 2015.

[Zha09] Chun-Ting Zhang. The e-index, complementing the h-index for excess citations. *PLoS ONE*, 4(5):1–4, 05 2009.

[Zyn13] Andy Zynga. Harvard Business Review: Where Open Innovation Stumbles. `https://hbr.org/2013/01/where-open-innovation-stumbles`, 2013. Published: 2016-04-23, Accessed: 2013-01-28.