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DEVELOPMENT OF A DATA CAPTURE TOOL FOR RESEARCHING TECH ENTREPRENEURSHIP

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1. Introduction

Established companies have a crucial role in maturing technology and improving the quality and functionality of improducts already in the market. The development seen here is usually incremental [Weber 2012], which is understandable as the companies are likely to have a good understanding of the market, the relevant technologies and the customers' needs and wishes. Conversely, startups and spinouts seek to address new needs in the market and/or leapfrog the quality of existing market offerings. Such startups gain their advantage in the market by leveraging a unique insight (customer needs, distribution channels or something else) or in some cases unique disruptive technologies. The latter case of technology entrepreneurship is a crucial mechanism for getting new knowledge and research to the market (innovation). Technology startups sometimes reach the market, but in many cases they act as an incubator for technology, maturing it to a level where larger companies can see the feasibility in adopting the technology – perhaps through acquisition, procurement or licensing. Despite the importance of these nascent companies to the commercialisation of technology, the process by which technology is matured and developed is largely unaccounted for. Entrepreneurship researchers would disagree, stating that the subtleties of the entrepreneurial context are well understood [Shane 2000a], [Lee and Venkataraman 2006], [Sarasvathy and Venkataraman 2011a]. As will be argued later, this is only partly true for "regular" entrepreneurship as current studies rely heavily on retrospective and predominantly qualitative accounts of the entrepreneurial process. In any case, the special case where advanced technology is at the heart of the venture is left entirely unaccounted for in research. On the other hand, design researchers could argue that this "supposedly" unique phenomenon is nothing more than a re-packaging of well known innovation research. Anticipating such contentions, the first part of this paper will focus on delimiting and differentiating the phenomenon of technology entreprenurship and establish a set of requirements for methods attempting to capture and analyse it.
In the subsequent part, this list of requirements will form a basis for evaluating the appropriateness of current information capture and analysis tools in engineering design.
The third part of the paper will review efforts undertaken at The Technical University of Denmark in developing a tool appropriate for capturing the necessary information from the phenomenon. The features of the tool and the type and architecture of the data produced will be described in detail and compared with the list of requirements established earlier.
Finally, the implications of the new tool are discussed and a number of suggestions are made regarding how to apply the tool in technology entrepreneurship studies and design research in general.

2. Methodology

To investigate the phenomening of technology entrepreneurship a number of approaches have been adopted; literature search, case studies, electronic surveys and method testing in the form of action

research [Greenwood et al. 1993]. The overall study can be seen as covering the research clarification and to some extent the descriptive study phase of the design research methodology proposed by Blessing and Chakrabarti [2009]. The first and third part of the paper, respectively concerned with forming requirements and developing a new method for information capture and analysis are very much inspired by the methodology proposed by Cash et al. [2010].

3. Technology Entrepreneurship and Design Research

This paper focuses on the specific topic of technology entrepreneurship. There are two reasons for this particular focus; one is that design research is on firm ground with technology development but has only covered the topic of entrepreneurship to a limited extent. The other reason is that entrepreneurship research (traditionally a subset of business management research) is largely oblivious to the role and significance of technology in startups. Both points will be elaborated upon in the following sections.

3.1 The role of technology in entrepreneurship research

Entrepreneurs and the discipline of entrepreneurship as fields of research is a somewhat novel concept. Since the dot-com bubble of the early 21st century, the field has received increased attention and several scholars [Dew et al. 2009], [Sarasvathy and Venkataraman 2011] have managed to identify a number of distinct characteristics for the entrepreneurial mindset and process. The central notion of *effectual entrepreneurship* was coined by Read et al. [2010] and it refers to the result oriented mindset of the entrepreneur/team and the tendency for dispositions to change drastically and unpredictably when faced with changing perceptions and market conditions. Another popular contribution is that of Ries [2011] who introduced the idea of a *pivot* as a state change where the business idea (including products and services) changes character completely to better accommodate new user needs or changes in competition, market conditions, financial conditions or intelectual property. Most, if not all of these studies are based on retrospective accounts of the processes undergone. It is a well known fact from design research (and other fields for that matter) that such end capture techniques are likely to be incomplete and perhaps even misleading. This post-rational approach to the process is often supplemented with a keen interest in the traits of the entrepreneur [Shane 2000b], [Nielsen and Lassen 2011]. Only a few studies have attempted to delve into the actual processes undergone by the entrepreneurs in developing their business. One example is the studies conducted by Mueller et al. [2012] who ask the question: *"What do Entreprenurs Actually Do?"*. Despite being a step in the direction of actually understanding what constitutes the entrepreneurial process, the study limits itself to comparing the behaviour of early stage and later stage entrepreneurs. Common for all of these studies is the almost complete absence of technology and its role in the startup. This indicates the (mental) origins of Ries and many other entrepreneurship scholars; Silicon Valley. In this epicentre of business venturing, the vast majority of entrepreneurs are involved in software, hardware (electronics) or a combination of the two. This means that the businesses being created sit on extremely scalable and adaptable platforms making technological issues a matter of time, code, silicon and capital. Conversely, as countries such as Germany, Denmark and Sweden have a tradition of and strong knowledge within creating industrial products such as cars, planes, truck, pumps and wind tubines. Clearly, such technologies require added attention and larger resources to reach the market. Hence, the importance of extending the focus of entrepreneurship research to include technology based instances.

3.2 The role of entrepreneurship in design research

Since the seminal works of Hales [1986], the design research community has been very much aware of the importance of capturing and analysing the processes involved in engineering design and thereby have establish an understanding of the nature of such processes. More recently, Badke-Schaub et al. [1999] have borrowed approaches from psychology in trying to better understand the role of the single designer and the group in such processes. These and many other studies like them, tend to gravitate toward the design processes seen in established organisations and for good reason; such organisations are the main drivers for bringing new products to the market and improving the quality of existing products. Furthermore, design projects in such companies pertaining to the same market or technology

area are likely to be similar in nature. Figure 1 lists a number of knowledge areas needed for successfully bringing a product to the market. The list is non-exhaustive and is merely provided to support the following point: For development projects in established companies much of the knowledge needed for creating the product and bring it to the market is already present. In such a project, there will probably be a need for creating small bits of knowledge within a number of areas and perhaps certain (single) areas require a larger amount of new knowledge. Such a design effort could be characterised as incremental innovation as it is mostly based on existing knowledge.
This incremental nature of knowledge creation in established companies is in stark contrast to the nature of knowledge creation in startups. Here, the bulk of knowledge needed to run a company is likely to be unknown. In a market driven startup, there might be a unique insight (knowledge) in the market or a customer need. Based on this starting point, necessary knowledge from other areas is attained. In a technology drive startup, the same process is true – except, here the unique insight is within the technology. As time passes, the knowledge accumulated will move the startups toward the right side of the continuum and eventually turn them into established, well-functioning companies.

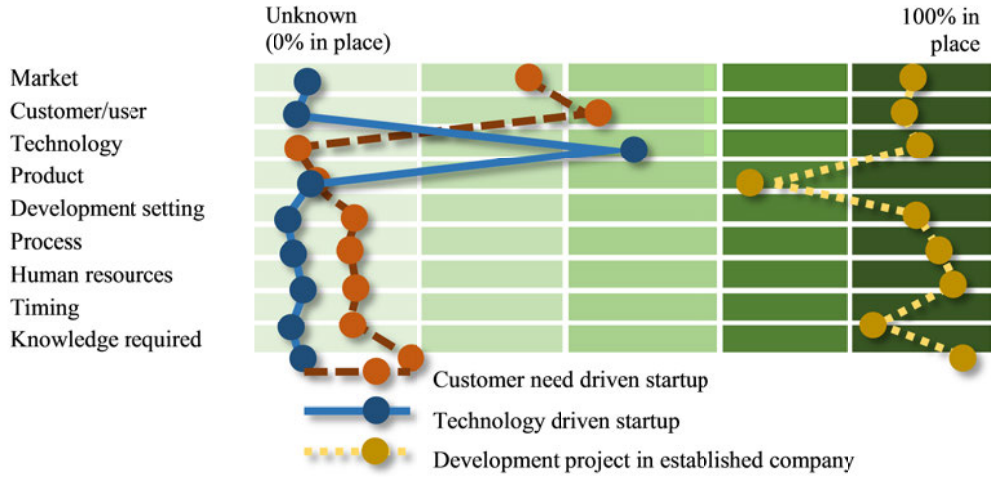


Figure 1. The difference in established knowledge for startups and established companies

4. Requirements for information capture and analysis in tech entrepreneurship

As established, there is a need for properly understanding how startups are built based on advanced technology. In this section, the prerequisites for any tools or methods attempting to do so are explored and a list of requirements is created. These requirements have emerged from consulting literature on entrepreneurship [Shane 2000a,b], [Ries 2011], [Sarasvathy and Venkataraman 2011b], [Mueller et al. 2012]. Many of these requirements were verified and new ones aded by a survey done with 10 tech entrepreneurship teams – the same survey is mentioned below in the section *Testing the Development Log*.
Also, the work of Cash et al. [2010] on how to design appropriate techniques for capturing and analysing data has been used. Specifically, the study by Cash et al. highlights the importance of structuring data and creating standardised research techniques and measures. Also, the importance of triangulation – i.e. reaching the same conclusions by different approaches and using different sources is identified as being a key element in reaching statistically significant and scientifically rigorous results. Table 1 lists a number of requirements for capture and analysis tools and methods. In the comments, additional notes for each requirement are provided.

Table 1. Requirements for new tool or method

Overall area	The tool/method needs to…	Comment	Source
Topics areas / disciplines	… Be multi-disciplinary	Topics including engineering, business development, legal issues etc.	[Shane 2000a], Own survey
	… Be multi-perspective	Perspectives could include activities,	[Shane 2000a], [Mueller

		communications, data, boundary objects etc.	et al. 2012]
	… Be unbiased	The important topic areas and perspectives are unlikely to be known beforehand	Own survey
Setting for data collection	… Capture dispersed efforts	efforts are likely to unroll on a variety of locations; in the office, on the bus, with a customer, in the sparetime etc	[Shane 2000a], [Mueller et al. 2012]
	… Comply with non-specific support tools.	and ever changing) support platforms (project planning tools, visual representations, web-tools etc.)	Own survey
Time span and timing	… Capture various time spans and spontaneous initiation	certain projects are killed within days, others continue for many years. Projects will start and end at seemingly random times.	[Mueller et al. 2012], [Dew et al. 2009]
Temporal resolution	… Capture long term data	Many startups are done in the sparetime and often long periods of time pass without activity.	[Mueller et al. 2012], Own survey
	… Capture near-instantaneous changes	Pivots occur at random times and it would be useful to have strong data on the time right before and after the change happens	[Ries 2011], Own survey
Interference with process	… Resource efficient or require no additional resources to use.	Any non-constructive interference with the process is unacceptable.	Own survey
Value creation for design team	… Able to provide immediate satisfaction	Little meaning in learning for the next project as it will be different	[Dew et al. 2009], Own survey
Research related require-ments	… Produce replicable data	For the tool and method to provide data and insights of valid character and general utility, the output must be standardised and structured in a coherent way.	[Cash et al. 2010]
	… Capture the project context	For the research community to properly analyse and distinguish between different cases by precisely defining the context of the project.	[Cash et al. 2010]
	… Multiple sources of proof (triangulation)	When statistical significance is absent, it is very useful to have other sources of proof available.	[Cash et al. 2010], [Snider et al. 2012]
	… Capture a statistically significant amount of data	The projects seen in (technology) entrepreneurship are by definition dissimilar. Many infuencing factors will inhibit the possibility if general conclusions. To mitigate this, large, structured data sets from a large number of cases are needed.	[Cash et al. 2010]
	… Capture appropriate data	The data captured should be appropriate for documenting the phenomenon and excessive capture of non-essential data should be avoided.	[Cash et al. 2010]

5. Evaluation of existing capture techniques

Having established the requirements for research techniques used in technology entrepreneurship, the next step is to gauge the appropriateness of existing techniques used in design research.

There is a mass of capture and analysis tools available for research into design projects [Shane et al. 1909], [Bracewell et al. 2009], [Cash et al. 2010], [Robinson 2010,2012]. Below, the current research techniques are discussed with regard to each area of requirements from (from Table 1).

Topic areas / disciplines: To create a manageable and intelligible data set, there is often a need to limit the focus of the study – for instance by looking at engineering inputs alone and not at marketing, quality assurance as was the case in the study of Hales [1986]. This delimitation is perfectly valid as engineering is often confined to a separate (and autonomous) part of the organisation. If such tools are to be used in researching technology entrepreneurship, many more topics would need to be covered. For such a wide focus to be successful, an efficient and structured approach for capturing and ordering the data is most likely needed.

Setting for data collection: Design projects in established companies and organisations are typically executed at a limited number of known locations. For the researcher this means that the location(s) of the laboratory is known and experiments can be planned and set up. For instance, in the studies by Badke-Schaub et al. [1999], researchers (engineers and psychologists) were able to observe the design team in the company (the workplace). In entrepreneurship the efforts are often dispersed and done in an ad-hoc manner at non-descript locations. One team member (an entrepreneur) might work on the project in his or her sparetime at home or on the train. On other days the setting could be team working session at a café. This capricious nature of the work makes capture techniques such as observation and interviews exceedingly hard to work.
Time span: In a "normal" design setting, the project is planned ahead and factors such as initiation date, duration and conclusion date are likely to be more or less known. This gives the researcher an opportunity to plan the study of the process and allocate the necessary amount of time and resources. Startups do not have any project road maps (at least in the early stages) and ideas are likely to occur at unpredictable times. Most of the known capture techniques require some degree of researcher participation and setting up of capture mehods. For computer/software based automated techniques [Bracewell et al. 2009], [Robinson 2012], this problem is mitigated.
Temporal resolution: Normally, one would assume that the team contributing to a development project is based in the company or at least they will be solving the development tasks during the normal working week –. This is also true for later stage startups, where the necessary resources have been acquired for hiring team members. Even so, it is not a given that the entire team will be working full time for the startup. In the crucial early stages of a startup, where the technology is being explored and the commercial potential uncovered, the team will often be working on the project in their spare time or whenever the opportunity is there. This has the effect that the progression of the project will not be stable and gradual. Rather, progress is likely to happen in chunks of different sizes and at unpredictable times. As with the time span and timing issues mentioned above, this complicates the process of capturing data. In his 2,8 year long study of an engineering department, Hales [1986] managed to capture 1373 interchanges or separately identifiable events with a duration down to 0,1 hour. This did however require *"1180 pages of diary notes, 76 hours of audio tape recordings, 116 weekly reports and 6 full design reports."*
Interference with process: Resources of any kind (human, capital, knowledge) are scarce in startups. As already stated, the entrepreneur often has to progress the startup in his or her sparetime. Also, the amount of tasks that need to be done will always greatly exceed the amount of time available for solving them. In such a resource starved process it is unacceptable for the entrepreneur to allocate time to non-essential tasks, such as discussing the project with a researcher, waiting around for an observer or filling in forms to document progress. This is a dilemma with regard to capture techniques as most of them need some kind of effort from the entrepreneur – even the non-participating observer can be a chain around the ankle for entrepreneurs in need of agility and quick response. An exception to this is the software based capture techniques that capture data from software already being used by the entrepreneur. Robinson's [2012] method of using personal data assistants to capture data in an unobtrusive way comes close to meeting these criteria. One could however argue that the data gathered (concerning work tasks and satisfaction levels) is not necessearily of interest to the designer at that particular moment.
Value creation for design team: Mature development organisations are likely to have certain models in place for managing and navigating the development project. These models can be used over and over again because the similarity between projects is very close. Because of this, the experiences gained from one project are likely to be relevant for future projects. In the startup there is little meaning in trying to prescribe the process as this will inevitably diverge from the actual process unfolding. Futhermore, future projects are likely to be completely different (probably in an entirely new company) from the one currently being executed. This means that there is little meaning in investing time on learning from one project if those learnings cannot be used and that same project. Most capture and analysis techniques create value on the longer term [Hales 1986], [Badke-schaub et al. 1999], [Bracewell et al. 2009], which will not provide the necessary motivation for using them in a startup context.

Research related requirements: As these requirements are general for all capture and analysis techniques, there is no need to elaborate on why this is also the case for techniques used in the context of technology entrepreneurship. Cash et al. [2010] provide excellent insights on the research related requirements listed in Table 1.

5.1 A need for new techniques for understanding tech entrepreneurship

Having now gauged the appropriateness of current capture and analysis techniques for use in tech entrepreneurship projects, it is clear that there are a number of shortcomings for current approaches. To gain a better understanding of how technology ventures develop, new approaches are needed. This is the concern of the the last part of this paper.

6. Development of a capture and analysis technique for tech entrepreneurship

To build a technique appropriate for capturing the nature of technology entrepreneurship two central challenges had to be addressed; one was getting to a notion of knowledge creation (design) able to encompass any topic relevant to the entrepreneur. The second challenge was to create a mechanism by which data could be captured without interfering with the process and drawing on scarce resources. The considerations on these points will now be described in more detail.

6.1 A basic notion of knowledge creation

In a startup knowledge needs to be created or attained within a vast variety of fields; everything from the technical solutions in the product to the legal structure of the company formed can prove to be of grave importance to the success of the venture. For this reason, the approach developed should be able to capture this multi-disciplinary phenomenon while at the same time not being cumbersome.
To understand the accumulation of knowledge in a startup, several cases of technology entrepreneurship were followed – 11 cases in the context of a course on entrepreneurship and one case in the context of a master thesis on technology entrepreneurship. Based on these non-structured observations, a general model was developed (see Figure 2).

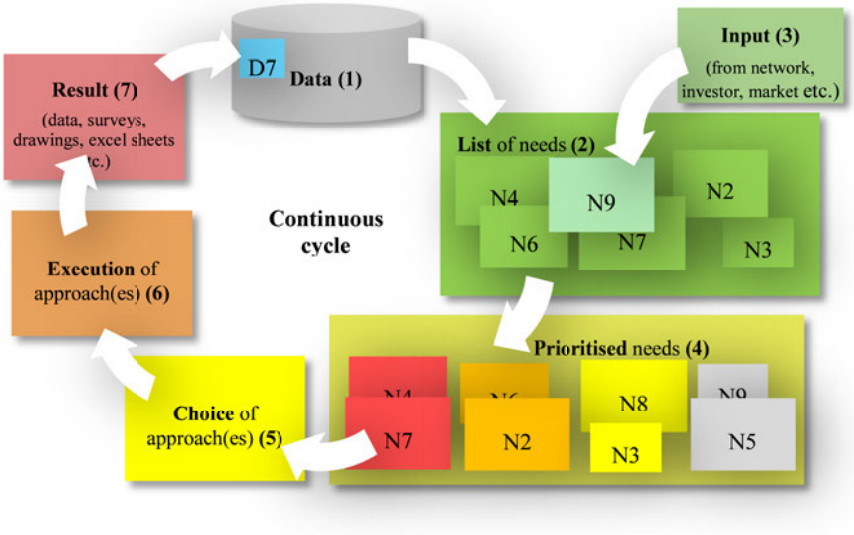


Figure 2. The accumulation of data (knowledge) in a startup

In this model, any project starts with a dataset (1) containing little or no data – in the tech entrepreneurship case, the data is likely to be on the technology (patents, drawings, calculations etc.). With an overview of the existing data, gaps can be identified and needs for new data can be formulated (2). These needs can also be identified based on outside inputs (3). When a gross list of needs has been formulated, the ones most crucial to the progression of the project will be identified (4). For each of these prioritised needs, approaches for adressing the need can be identified (5) and

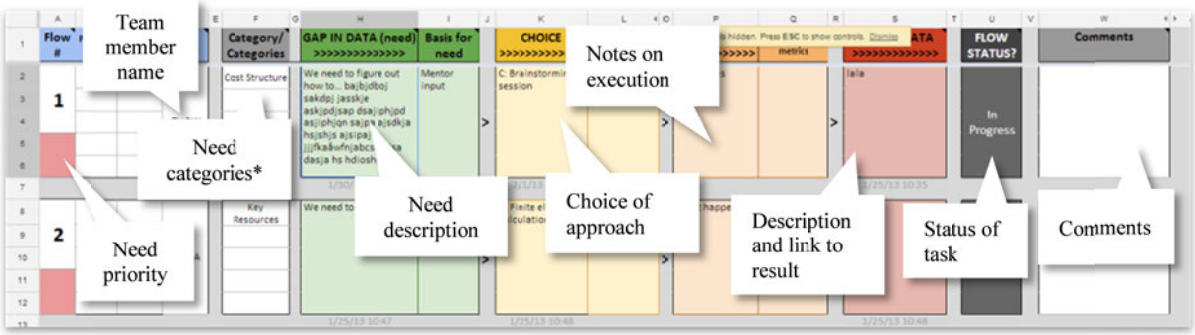
subsequently executed (6). The result coming from the chosen approach (7) then goes into the data set (1) and the whole cycle can start over.
As an example, start-up A could at a certain point in time realise that it lacks an understanding of how much noise is emitted from the product being developed (1). This is important, as the target customer indicates that noise levels are a critical issue (3). On this basis, the start-up realises a need for knowing the noise levels (2) and due to the customer's insistence on the issue it is given a high priority (4). One entrepreneur in the company is aware of a measurement tool which can be used for gauging noise levels and this is chosen as an approach (5). The tool is bought and the measurements are performed based on the instructions in the manual (6) and the results are registered and saved to an excel spreadsheet (7).
This model should be applicable to any case of need driven knowledge creation, and contains many of the vitues of the DREd issue driven design rationale editor.

6.2 Motivation for creating and sharing data

One thing is to establish a model for how data is created; another thing is to use the model for extracting data. As described, there is little sense in asking the entrepreneur to spend time and other resources on providing data for the researcher unless an equal or larger value was returned immediately. It was realised, that for this to be possible the capture technique would somehow have to be integrated into a tool useful for the everyday operations in the startup. This has the potential problem of adding prescriptive dimensions to a technique that should be descriptive only. However, as no other way was found, a mechanism for creating value was devised.
As a background for this, it was already obvious that one of the main challenges for a startup was to manage the development process and ensure that resources were spent in a meaningful and effective way. As the model above already provides a structure for these management and allocation processes, it was decided that the value should be provided in the form of an increased overview of the current situation and the tasks at hand.
In other words, the tool (tentatively called the "Development Log") can be used by the entrepreneur as a way of structuring and coordinating the current efforts and the data created. The data gathered while the entrepreneurs do so is then logged in a central database and made available for research purposes.

6.3 Testing the Development Log (version 0.1)

To test the Development Log, an alpha version was created using Googles online services (spreadsheets and surveys) – see Figure 3. This alpha version was tested on 10 student teams working with technology entrepreneurship. This test enabled a validation of the general usefulness of such a tool and also provided a number of insights as to what types of data one could expect from the tool.



*The categories used were from the Business Model Canvas by Osterwalder et al. (2005)

Figure 3. The alpha version of the Development Log

To ensure that all experiences were captured, all teams were asked to respond to a suvey. Members from 8 teams responded – 23 responses in all. This feedback generally acknowledged the value of the tool, but most respondents also asked for improvements in the interface and the number of errors in

future versions. Also, the spreadsheet based overview was har do navigate once the amount of data put into the sheet got over a certain level.

6.4 The updated Development Log (version 1.0)

Spurred by the success of the alpha version, the development of a fully functional 1.0 version was undertaken with the help of financing from the Danish Industry Fund. This version is finished in January of 2014 and it will incorporate a greatly improved interface and many usability improvements. In figure 5 a number of interface mock-ups are provided (the actual interface was being finished at the time of writing).

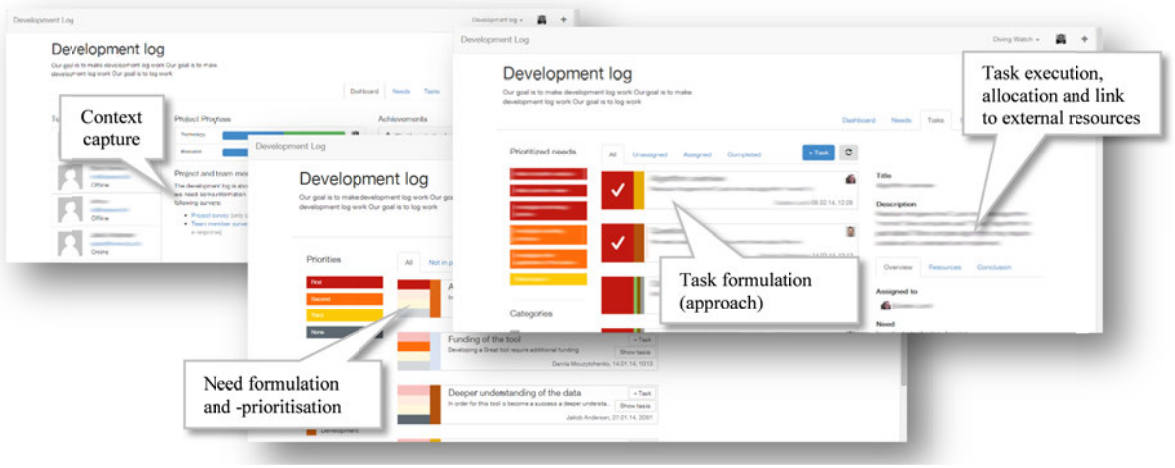


Figure 4. Development Log interface (version 1.0)

The tool is built using the HTML5 language, which makes it compatible with all modern platforms including computers running Windows, Mac OS and Linux. The tool can also be used on smartphones and tablets. The point of this is to ensure the ability to capture any activities – regardless of where and when they unfold.

6.5 The Development Log Database

The interface and general usablility of the tool needs to be in order for the tech entrepreneurs to actually use it. If that is achieved, the tool will compile all inputs into a structured database. The contents and structure of the database are shown in Table 2 in a simplified version.

Table 2. The Development Log database

	Linked to ...					Log frequency		Type
	Project	**Need**	**Task**	**Category**	**Team member**	**At project start**	**When changed**	
Project	✓					✓		
Mission						✓		Description (plain text)
Team members						✓		Finite set of names
Project evaluation							✓	Description (plain text)
Need	✓			✓			✓	
Description							✓	Description (plain text)
Priority							✓	Integer (1-3)
Task		✓	✓	✓	✓		✓	
Description							✓	Description (plain text)
Status							✓	Finite set of categories
Resources (links)							✓	URL to resource
Conclusion							✓	Description (plain text)

The first columns indicate the linkages in the data – for instance that each task is linked to one or more needs. Also, a task can be linked to other tasks that address the same need. Futher to the right, the frequency at which the information is logged is shown. Project specific (contextual) data is logged at the beginning of the project and the other data is logged whenever a team member edits a need or a task. Note that all log entries include a timestamp and the name of the team member editing entries.
To the far right, the type of data collected is shown. Many of the data elements are plain text inputs from the team members. This unstructured input type is hard to treat quantitatively and analyse in big amounts.

7. Discussion of potential applications and future developments

The Development Log has been designed based on the requirements described in Table 1. The log is a work in progress, but already in its current state it can provide unique insights into the phenomenon of tech entrepreneurship. In this final discussion, some of the potential uses are discussed along with some of the intended future improvements.

7.1 Understanding learning and problem solving in the startup

The log gives the researcher the opportunity to capture how needs occur and change importance over time in the early stages of the technology startup. Challenges to the progression of the startup can be identified – an approach reminiscent of the "critical situations" captured in the studies of Badke-schaub et al. [1999]. Also, the development log captures the approaches chosen for adressing the given need. These approaches can be compared to the performance of the team in order to establish if certain task formulations and sequences are more effective than others.

7.2 Tendencies in need categories and work content

The crude categorisation currently used for tagging needs can be used as a rough method for tracking the importance of certain topics over time. If supplemented by data natural language processing of the team's statements, more advanced analyses could be performed. The current intention is to eventually implement an automated natural language processing feature for identifying sub-categories of activities and other perspectives. Such a feature would most likely require the use of one or mode appropriate ontologies, which have not been identified.

7.3 A platform for prescriptive studies

In its current form, the Development Log (deliberately) does not prescribe the actions or approaches of the team. As the descriptive study reveals insights and potentials for positively impacting the processes, prescriptive measures will emerge. In future revisions of the development log, the intention is that such measures can be applied within the log itself, thus creating an excellent basis for comparing the positive (or negative) impact of the measure to the baseline data.

7.4 An open platform

The tool will be made available for all researchers and startups interested in using it. The research community is encouraged to share any case studies done using the tool with the intent to strengthen the foundation for research on tech entrepreneurship.

8. Conclusion

This study has shown that technology entrepreneurship has characteristics very different from those known in "normal" design projects and startups with little or no technological content. As such, technology entrepreneurship constitutes a distinct phenomenon in need of distinct research techniques. Also, it has been shown how current approaches in design research are unable to meet the requirements set out by this new phenomenon. The development of a new tool meeting these requirement has been described and the final result – the Development Log version 1.0 – has been described in detail along with its potential uses and implications. The tool is the first of its kind and it

holds the potential for large scale-, structured- and collaborative research into the important phenomenon of tech entrepreneurship.

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