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Framing and reframing – the emergence of design constraints

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Abstract
Open-ended problems provides a window for innovations, but understanding the actual problem is challenging. Typically, teams might settle on their first impression as the design problem. Such an approach usually ends up in, not a bad solution, but in a solution that might not solve the right problem. Radical innovation literature suggests that teams should challenge their perspective of the problem, e.g. frame and reframe it, before solving it. This paper presents a study of how framing and reframing contributes to determining the constraints of two different types of design problems. A project course provides the particular data for the study, the result indicate that technological oriented problems needs support that forces the team to diverge from their initial design vision and that radical oriented problems needs support that encourage deliberation in the team. In conclusion support is required to be flexible, in open-ended design tasks, to fit its purpose.

Keywords: Design thinking, design reasoning, innovation, concept development, wicked problems

1 Introduction

Radical innovation drives *new* solutions and *new* products; thereby it includes dealing with messy imprecise problems in the initial stages of product development. A key concern for designers–preferable before they sets off to solve the problem–is to understand what the solution should do, who should use it and in what circumstances anyone should use it [1]. Two examples of different types of open-ended problems, which are the inspiration for radical innovation, are those that include [2]:

- an opportunity to design a totally new solution for a new market
- the possibility to refine an existing solution for a new application area.

Nevertheless, concluding on the circumstances of open-ended problems it is necessary to assure that the design team starts from a shared view of the problem at hand. A conceptual view that describes how to understand and solve open-ended problems is the difference between problem-setting, i.e. the careful process of creating a joint perspective of the problematic situation [3][4], and problem-solving, i.e. the process stages from detail design to product launch, e.g. [5].

Different types of design challenges have been studied; e.g. wicked problems [6]; [7], learning from problem solving [4], cross-disciplinary problems [8], trans-disciplinary problems [9] and constrained problems [10]. Such types of problems have common features of fuzziness and ambiguity that provide a window of radical innovation opportunities, but they also confront the engineers by introducing the management of information of users (social, personal, imprecise) and visions of new solutions (technical, material, quantifiable). In this paper we apply the concept of design thinking, e.g. [11], as a term to describe how engineers and designers have to manage the early learning activities in an innovation process. It should be noted that we do not attempt to define and capture Design thinking but lends some aspects from the concept. In particular, iterations of divergent and convergent activities to investigate the problematic situation while simultaneously evaluating several candidate solutions [11], is one such important aspect Although still ambiguous, design thinking is becoming more evident at the heart of contemporary firms' concept development strategies, yet it is often adapted to fit the firm's culture. Dorst [8] conclude that understanding a design task is a special kind of activity, which includes the challenges of both complexity and ambiguity. It can be argued that an established product development process, for example consisting of a number of prescribed stages and gates (cf. [12]) cannot in solitude forecasts new product successes. In addition, it is suggested that the problem solvers, in this case designers and/or engineers, should be aware of their reasoning and the basic logics of the different problem types [13][8]. Part and parcel of designers' reasoning, or design thinking, is the creation of frames, i.e. an investigation of the core of the problematic situation resulting in a certain perspective of the problem, and the creation of reframes, i.e. the development of a new (better) frame. So, framing a problem situation means that the designers impose a view on the problem, and that view also points at a certain direction to follow. This creates "order" to a messy situation and denotes one out of several possible perspectives of the problem [14]. Some argue that the frames that are created should be reframed in the planning stage to settle the problem as early as possible (e.g.[12]), while others argue that the frames should emerge, and change, throughout the concept development stages in parallel with the design team's increased insights of the problem (e.g.[11]). More or less, prescribing execution of both structured and creative activities simultaneously [2].

During the creative work, designers easily become too enthusiastic about their own design ideas [14], risking addressing the wrong problem and jumping into conclusions too quickly [15]. The risk of addressing the wrong problem comes from a single view that neglects alternative frames. Accordingly, the capability to reframe or to impose alternative views is an utterly important capability in innovation projects. Dorst [14] explains the activities of framing and reframing as "taking a giant step back", "to reconsider the basis for the work" and "to rethink the view of the problem". Still, such investigation intends to search for information about the problem situation and about the potential users to, metaphorically speaking, develop the "walls of the box" to be able to think outside it when facing an innovation opportunity, or to create a product specification when facing a possibility of incremental innovation. We have earlier developed a process for need driven innovation, which we employ, not only in industry workshops, but also in student project courses. During workshops and courses we have noticed that understanding the open-ended design tasks challenge the teams, and also that they do not have sufficient support in the guiding innovation process to set the problem or to deal with the ambiguity of the task. Despite this, they often end up in fairly high-degree innovative concepts and/or solutions. This has pointed our interest to study how teams manage their open-ended tasks. How do they understand the task and how do they set up and agree upon the design challenge, or more in more straightforward words; how do design constraints emerge? Thus, this paper presents a study of innovation teams in order to, subsequently; create guidelines and/or methods for how to support problem-setting activities.

2 Study approach

The need driven innovation process that has been developed is called 4I4I, four I:s for innovation [16]. Simply, the process consists of four stages, namely inspiration, immersion, ideation and implementation. The process firmly advocates the guiding principle of having a user point of view for the investigation of a problematic situation. Basically, the process promotes diverging activities, i.e. exploration, but also converging activities, i.e. exploitation. The process goes from the identification of a problematic situation, identification of users and their needs into idea generation and ends with concept development and evaluation. Thus, it does not address later stages of a product development process, e.g. detail design and production.

The study presented in this paper is done in a project course in mechanical engineering. The course is based on the development of both innovative and sustainable products and is running for eight weeks. Empirical data has been collected over several courses from 2010, but two teams from 2014 have been in focus for this effort. Those teams were selected based on "maturity" in observed data, i.e. a pattern from studying previous teams became clear, that is they were challenged by the open-ended design task and struggled to think together. Each team consisted of 7 master level students from the mechanical engineering programme, one team consisted of all males (team called Snow) and the other team (called Space) consisted of 4 males and 3 females. All students in the course were at the start evaluated to assess how they fitted into teamwork by using teamology [17]. Teamology is developed at Stanford University and is a repeatable method that is used to group people into effective teams, that is, it addresses their preferences for decision making and information sharing rather than dividing them into homogeneous teams according to their competences. As such it make creative work more effective, i.e. reaps the benefits of divergent skills, but as far as possible, prevents "team war". Team war typically arises due to different preferences of how to proceed with the task. After the teamology test, the different project assignments were presented and the students were asked to announce their interest for participation in the different projects. Though, the teaching team did the final division into groups and into each assignment. The two teams that were in focus for this study was formed based on the students first and second choice, and in line with the result from the teamology test.

The design assignments for the two studied teams were dissimilar, but both teams got written design briefs (one A4 page) as a start. The first team, here called team Snow, had the task to solve a problem related to 3D printing. Their design brief included a question; 'How can large scale 3D-printing be accomplished using snow and ice as construction material?'. Here there was no client, but a potential new market segment was provided as inspiration. Hence, the *Snow* team had a fairly defined area to start from and also a defined function of the 3D-printer. Yet, they were challenged by the novelty in the material and the up-scaling of the hardware. The second team, here called team *Space*, was given a theme and an area as inspiration. The theme was 'waste' and the inspiration area was 'space'. They also had a client, i.e. Spaceport Sweden [18]. They were challenged by a high degree of 'unknown' factors to investigate; subsequently they were also challenged by their own preferences of an engineering task, i.e. the start from a list of defined product requirements. Hence, they had a really open-ended design task. Despite the different design assignments, both of the teams had to start by framing the problem they were going to solve. Yet, they had to work on different levels of details. Both of the teams did reach a high degree of innovative solutions, and did succeed in developing the concepts into functional prototypes. The teams were also assessed as successful by the teaching team and the client.

Participative observation of teamwork has been the main source for gathering empirical data, but, also regular meetings have provided useful data. Participative observation includes the possibility to ask questions to the students while working. Being part of the teaching team and acting as a supervisor have provided the opportunity to ask "why"-questions and to encourage the students to explain and clarify their reasoning (cf. reflection in practice [4]). Here it should be mentioned that the teaching culture is based on equality and deliberation, rather than teachers possessing the right answers. Field notes were taken and a research logbook was written during the data acquisition, these notes have provided the main data for the analysis. Moreover, the students also write project logbooks were they reflect on their processes and learning activities. These have provided additional data for the study. The data was firstly analysed by one of us, and secondly a new analysis was done together. Thirdly, a model for problem-solving has been used to make sense of the observations, the model developed by Dorst [8] is presented below.

3 Design reasoning and problem-setting

Designing means to transform an existing problematic situation into a new preferred one [19], or in simpler words; change what *is* to what can *be* better. In line with the design logics, innovation includes the management of open-ended or wicked problems [6]. When managing an open-ended problem there is no single answer to the problematical situation, but several plausible. This particularly holds true for new concept development or radical innovation activities. Concept development includes both 'unknowns' and 'knowns' and to create understanding of the problem situation the designers have to temporarily agree on certain conditions. Kurtz and Snowden [13] have created a sense-making framework, called Cynefin, which visualize that making sense of open-ended problems rely largely on the team members' capabilities to break out of old ways of thinking and finding powerful interfaces between ordered and un-ordered domains. The Cynefin framework addresses the expectations of cause and effect, rational choice and intentional capability in human interactions. The framework shows that it is not suitable to approach an open-ended situation believing that there must be a right or ideal way of understanding the situation, that decisions are made of people possessing complete information, and that we ourselves can accidently do things, but that others do things deliberately [13]. Dorst [8] provide a basic, or as he calls it "a sparse" model for problem solving (see Figure 1).

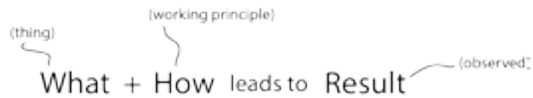

Figure 1. Basic model for problem solving, adapted from Dorst, 2011

Dorst [8] exemplifies that any of the elements in the model, i.e. 'what', 'how' and 'result', can in a design situation be replaced with question marks representing that there are unknown information. For instance what and how might be known but the result is unknown, Dorst [8] suggests that it can be derived from the known elements (Figure 2). In our interpretation this is similar to the execution of a product development process that is effective under certain conditions (e.g. [5]). Dorst [8] provides the example: *"if we know that there are stars in the sky, and if we are aware of the natural laws that govern their movement, we can predict where a star will be at a certain point in time"* (p. 523).

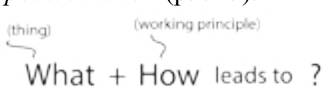

Figure 2. Problem solving model including unknowns, adapted from Dorst, 2011

Drawing from Dorst [8] model, a truly open-ended design situation can be described as consisting of an unknown ‘what’, an unknown ‘how’ and an unknown ‘result’.. That is; what thing + how to do it leads to a preferred changed situation (whatever that is), see Figure 3. Simply, the design team do not have precise information about what they should do, how they should do it and what it should lead to, i.e. a truly radical innovation opportunity as described by Randall, Harper and Rouncefield [1], but also a risk of too early jumping into solutions for the wrong problem since the designers are ‘forced’ to just start gather information of any of the topics.

? + ? leads to ?

Figure 3. Radical innovation opportunity, inspiration from Dorst, 2011

Another interpretation of Dorst’s [8] model that we have done in this study is that it, not only shows problem-solving (defined as execution of the activities to solve a known design task, cf. starting from a product specification), but also problem-setting if it is challenged by changes in any of the included parts. Changes in the included part are a default state for an open-ended problem, that is problem-solving also include problem-setting (cf. [3]).

The model in Figure 3 describes the problem-setting/problem-solving task assigned to team Space. They were only provided with a theme (waste) and an inspiration area (space), meaning that they did not know what to do, how to do it or what the results were expected to be. As engineers they were truly challenged by not being provided a product to start their process from, they were forced to understand the meaning of the words. Team Snow’s assigned task is more in line with Figure 2, yet their ‘how’ was unknown to them. That is, they were assigned to investigate *how* snow and ice could be the material in large-scale 3D-printing, i.e. what thing to use (3D printer) and the result (3D printing in snow and ice) were known. Nevertheless, the known parts did include some unknown information, some information could be retrieved by investigating what was known, for example about 3D-printing in plastic filaments. The observed activities to investigate and settle respective teams’ open-ended design assignments are described as frame (an initial perspective of the task) and reframe (a changed perspective of the task). These frames subsequently provide them with the constraints (e.g. specifications and/or “walls of the box”) that bring “order” to the open-ended problem.

4 Frame and reframe to develop constraints

Team Snow quickly accomplished the task of defining the core problem based on the given design intent. Team Snow explained and argued for going further with their work and start to create ideas for a solution. They were using Internet to search for more information and started to discuss the functions of the solution. During the information search they could not find any similar existing product, instead they started to browse similar technologies. They stated that this information could be useful later on. Team Snow discussed the problem that they had identified in relation to a potential user’s needs, and they agreed that their task should be seen as a technology development challenge, i.e. getting a technology to work before knowing the market and defining what the solution should do on that market. Realizing that they had very sparse or little experiences of the problem area, they agreed to develop rough prototypes to understand it, i.e. build simple delimited prototypes, make tests and explore practically what works and what does not. Team Snow built their prototypes from ‘scrap’, other cheap material and existing hardware that they modified. By doing so, a large part of their time was spent on building and testing. The team did not use drawings or simulations, but rather the parts they had available to experiment with led them forward. The first round of experimentation did not work as planned; they modified the prototype and tested it again, while doing so new concepts came up. Some of the new concepts were tested as they came up, and they were named after their critical function, for example, ‘the pump’ or ‘the fan’. During the experimentations, the team members seemed to be driven by passion in knowing more details, but also there was a sense of competition in the team. It could be observed that some members advocated their own ideas and both naïvely and purposefully made the best for them to become candidate concepts, i.e. making them work.

In experimentation activities, team Snow derived some reference data from similar technologies and similar product to make reflective questions, for instance “What is a reasonable print volume per time unit? The team also followed the creative suggestions provided by the defined process. For example not knowing where and with what to start, they just decided to “start somewhere” and decided to go for an approach to “get something to work”. From this the team framed the problem to be a form of ‘extruder-technology’ challenge. They settled the problem to be “water in some state that should be transported from a container to a nozzle and extruded as a snow and ice string”. From this they started to focus on those parts of the 3D-printer that handles the extrusion of material, simultaneously delimiting the challenge by for example excluding the control system. That part was found to be plausible to derive from existing 3D printers.

In parallel with the experiments team Snow divided the challenge into different areas based on earlier perspective of the problem, e.g. ‘transportation’, ‘extrusion’ and ‘storage’. The team agreed to build and test two new concepts and two old modified concepts that originated from the different areas, thereby they identified sub-problems. The sub-problems were specific to one or a few technological domains, but there were also some cross-disciplinary and general functions, for example, sustainability and phase-change. It could be observed that the sub-problems led the concepts further, for example in statements like: “– Ok, this works, but how do we solve that [sub-function] then?” This reflective process also sorted out non-functioning concepts. After several iterations of experimentation and modifications, the team decided to go with one type of technology that was not part of the initial selection of suitable technologies, but could be argued to be a result of the frame and reframe activities. From this perspective, or settled problem, the team were able to develop constraints and put together a specification for a solution.

Seemingly, team Snow did not encounter any problem to define their problem. They were very eager to start building and testing almost from the beginning indicating that they had some shared perspective of the challenge. When the team generated possible solutions they already had plenty of ideas and concepts that they wanted to test. On a regular meeting Team Snow presented four concepts that the found the most promising representations of their design task, and they argued for the pros and cons that they anticipated for each of their concepts. They got the advice from the teaching team to focus on critical functions of each concept, i.e. to find out what was most important of their concepts. From this they developed functional prototypes for testing to further refine the concepts. The team identified one critical function to be ‘transportation of the material’, the concept was named ‘Screw-fed snow’ and from that frame of the problem they used an ice drill and sewage pipes to experiment and test a plausible solution. From the experiment they learned that the texture of the snow was critical to the transporting function, for example wet snow clogged the pipe.

Team Space started in confusion of what to do and asked for better guidance. They were encouraged to define keywords from the design brief and to use the themes as a start. Still in confusion, the team was told to grasp something that interested them from the themes and from the inspiration area, but also that they should be visionary within the sustainability domain. At this time, not knowing what the problem to be solved was, they were really frustrated. After discussions, the team agreed to find 'something that could be of use for someone', and got acknowledged by the teaching team for making an effort to follow the prescribed process. Team Space made an effort to find an interesting problem by exploring the themes and the area, settling on base the interest on their own seemed to help the exploration. Holding on to the theme 'waste' they started to focus on plastic packaging material, the inspiration area gave them a context of a public place 'space house'. In relation to the theme, the students discussed mixing of combustible waste, they asked themselves "How can it be easier to recycle than it is today?" This led to another exploration of new keywords. They elaborated on how they perceived themes and meanings, while also investigating how others said about them. After three weeks the team was supposed to present a concept, this stressed them to take a decision. In order to reach consensus they decided to conclude on keywords that they felt were most important and from them create a new design brief. They found that the important keywords were: user friendliness, decreased volume of waste, automated system, sustainable system and healthy. The derived the keyword, decreased volume, from a discussion about self-sufficiency and related it to plastic packaging. They argued that there was too much plastic waste in the comestible bin, since there were too many other bins stored under the sink in the households (note: household waste is in Sweden sorted in the kitchen and stored there until transported to a pick up point). This problem, they said, resulted in mixing recyclable plastic into the combustible waste. If plastic material should be fully recycled they concluded that it should be done in the household. A way to reduce the volume of plastic was then decided to be the development of "a device adapted for households that in an efficient way reduces the volume of stored plastic packaging material". Their new design brief was questioned in a regular meeting, the teaching team suggested that it was too wide, but it was discovered that the Space team had developed unexpressed boundaries for the challenge. They explored the keywords once again and wrote a short explanation of each word, by this also articulating the meaning of them.

Having this shared understanding in mind, the Space team generated ideas, clustered them into categories and generated concepts from those activities. The team selected the three most promising concepts and developed them further, mostly based on associations to keywords and by searching for more information on Internet and in the library. Weights were developed for each concept based on the keywords and the articulated meaning of them. Weighting was then executed using a decision matrix. The team decided to continue with a concept that used plastic packaging material and turned it into filament to be used as raw material for household 3D printers. Team Space decided on a rough design, which was divided into three parts depending on their critical functions. They made a simple mock up in paper to understand the size and the assembly; also they used existing solutions to experiment and test, e.g. a grinding mechanism. After this, the Space team started designing and constructing a final concept, and they made a complete CAD model. Subsequently, the CAD model was used to refine the concept.

5 Making sense of open-ended problems

The activities of the respective team showed different approaches, but also common reasoning in understanding their tasks. Team Snow and team Space were challenged by different types of open-ended problems. Snow had, as they also expressed it, a technological oriented problem. Their problem was open-ended in respect of 'how' (cf. working principle, [8]), but also in some degree in respect of 'what' and 'result'. Nevertheless, their frame and reframe activities to understand the challenge addressed mainly how to use snow and ice as 3D printing filaments. Team Space had what we call a radical oriented problem. The team members were really challenged of its wickedness and ambiguity, but in the end proud that they had managed it. What can be called the constrained problem became clear for team Snow in the first few days, but team Space struggled to understand their challenge until the third week. Having regular meetings made it doable for all teams in the course to compare their processes, and team Space was stressed of being 'late'. However, both teams delivered a final concept and a functional prototype in due time. A pattern for how team Snow reasoned to understand their challenge is visualised in Figure 4. Team Snow was challenged to understand how snow and ice could be used as the material in large scale 3D-printing. They were quick to frame the problem in a 'transportation' perspective, i.e. extruded snow. By doing so they decided that the 3D printer hardware was part of the problem, but not the critical function. In terms of developing constraints this can be viewed as a first boundary of their specification.

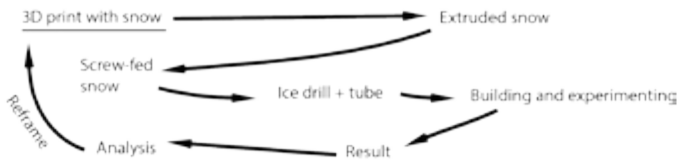

Figure 4. Team Snow – frame and reframe.

Team Snow developed their concepts from that first boundary, they experimented, made tests and designed new prototypes to go into further detail. They had a strong focus on finding a suitable working principle, and the hardware, to solve the problem but was in their process of exploring also changing their understanding of the result. A better understanding of the problem leads them to reframe and set up new experiments. Overall, the frame and reframing were a comparison between the expected behaviour (of Snow and ice, or of the 'transportation') and the results in their experiments. This approach was iterated and in parallel the team members' gained clarity of the challenge and better understanding of how to make it work. A pattern for how team Space reasoned to understand their challenge is visualised in Figure 5.

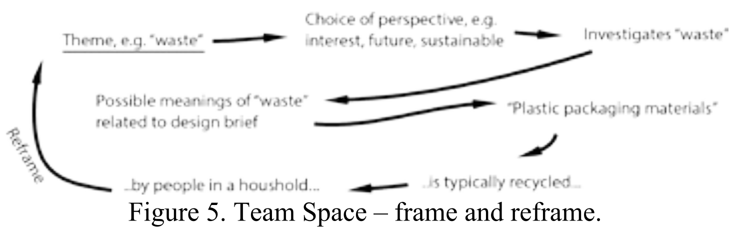

Figure 5. Team Space – frame and reframe.

Team Space was challenged to understand what to do, how to do it and what result it should lead to. They started analysing the instructions, i.e. the initial design brief, to understand what the teaching team expected, rather than what they themselves identified as an innovation opportunity. At this stage, they needed to be motivated to do their best to make sense of the challenge. They were instructed to explore what meaning they prescribed to the theme in relation to the inspiration area.

In order to make an analysis they were also directed towards a visionary view. The exploration of the theme gave them keywords that made sense of the task, e.g. plastic packaging materials, recycling and household. From this exploration of the meaning of the words, the team defined a new design brief. This one reframed the challenge into the investigation of how a household can store and recycle plastic packaging material in a sustainable way, or as they simplified expressed it "how to turn waste into an asset?" From a perspective of a 'result', i.e. decreased volume of waste under the kitchen sink, the team elaborated on different concepts to find some use for the waste in the household instead of storing it. When the team generated concepts they found constraints in their own design brief, i.e. the reframed challenge, which made it doable to focus on critical sub-functions of the problem as a whole. After a few weeks of struggle, the Space team could design a rough concept in a CAD program, i.e. a first view of 'what' they were actually going to develop. From this, they could derive working principles and test the object's actual behaviour.

Both teams did recognise the importance of 'just start somewhere' but due to the different nature of their open-ended problems they started on different levels of abstraction. Team Snow, as we interpret the observations, was confronted of their first constraint and their process described diverging actions, or widening of perspective, in order to solve their task. By doing so, they could obtain information on 'what' from their elaboration of 'how', i.e. their delimitation to not especially address the 3D printing hardware might have been a sound frame and did progress the work. Team Space, as we interpret the observations, was challenged of understanding the task (at all) and of creating a shared design vision. Their process described converging actions, i.e. narrowing the task to find direction. By doing so, they could not only create a shared frame, e.g. manifested in their own design brief, but they could also find constraints to start generate ideas from. Both teams made experiment to create frames and to reframe, yet they had different 'materials' to experiment with. Team Snow had observable and tangible results of their experiments, for example they could improve their equations and calculations. Team Space had to create meaning to their intangible results, for example articulate definitions of words and relate them to how users could perceive their concepts.

6 Concluding remark

In this study we have been seeking clarity for how design constraints emerge in open-ended problems. We have observed that it is important to create learning situations, i.e. to allow students to test their assumptions and to encourage experimentations. However, the learning situations were different for the two cases. In the case of team Snow, where the problem was relatively concrete, the team needed support to diverge. In this project the team were encouraged to build simple prototypes to quickly test their frames (assumptions) and be able to reframe. That is, the team got the opportunity to choose strategy by themselves and converge on a solution they found the most interesting, logical, plausible, etcetera, but they were also encouraged to locate a critical function and test it as soon as possible. In this way, the team's overall activity became divergent as they covered a large number of frames before they froze and created constraints. Support therefore needs to inspire the team to experiment in rapid iterations with the opportunity to reflect on the results. In the case of team Space, where the problem was only vaguely hinted at, the team needed support to dare to converge even more. The team created frames by examining the information they received in the design brief. Thus the problem became wider and the team needed support to stay in this uncertain area until a pattern, i.e. a sort of logic appeared. This was mainly achieved by focusing on things that interested them so that they could maintain the exploratory focus. It was found important that the learning activities should be based on democratic elections, testing different methods, organizing and visualising information, etcetera. In the end, the diverging activities provided information to enable converging activities. One support that is needed is to inspire exploration so that the group sees a point in searching for information without a direct measurable purpose. The frames that the team set up were tested mostly with the help of literature and faculty at the university, or by discussions within the team. Thus, different frames were examined before the group formulated a problem, i.e. decided upon and set up the design constraints. In conclusion, this study exemplifies that–in opposite of what students prefer to do–widening the problem (diverging) is beneficial for learning and for innovative solutions. Yet, support that takes the different situations into account needs to be further investigated and developed.

Acknowledgement

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