Workplace problem solving within the design process

The story of Pekki table

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This paper presents the story of creating the design table, Pekki – from the initial idea to the manufactured product. The story provides a background for further conceptual analysis. A Finnish cabinetmaker Matti Salminen revealed to us his dream to make a table with distinctive lines. He agreed to be our partner in this study, and we documented the entire project. We closely observed Matti in his workshop, where he explained what he was doing and in the process verbalized his thoughts and actions. We produced field notes, interviewed Matti, informally discussed, made video recordings, took photos and collected Matti's drawings and sketches. Along with the documentation, we attempted to conceptually understand what happened during the process. Our preliminary intention was to examine how problem solving appeared in the process of manufacturing the prototype. It became evident that problem solving situations do not only occur in specific instances of the process, but the process itself was deemed a "problem solving" situation. Moreover, the settings unveiled that creative and design processes were intertwined with problem solving. The aim of this paper is to shed light on and open the difficult ponderations between problem solving in addition to creative and design processes, by answering the following questions: 1. What is the cabinetmaker's process of designing and creating a table? 2. How do the problem solving situations influence the process, and what is the role of the jigs within the process? 3. How are the processes of problem solving, design and creative process intertwined? Based on our findings, we conclude that problem solving has a mediating role between creative and design processes.*

Keywords: workplace problem solving, design process, creative process, cabinetmaker

Introduction

This study is a part of a project regarding workplace problem solving. During the preceding stage of the project we gathered data among a group of cabinetmakers regarding their everyday tasks and problem solving. In the latter stage of our project, we felt the need to observe and document one of the cabinetmakers' tasks from inception to conclusion, in order to explore the problem-solving situations that presented itself. At this point, one of the cabinetmakers, Matti, revealed his intention to craft a table with distinctive lines. At this stage the idea was still floating about in his head, but he had no definitive vision in terms of what it would look like. We documented the process of construction of the table named Pekki, by Matti, the cabinetmaker and how he manufactured the prototype. The preliminary intention of this study was to examine how problem solving appeared in the process of manufacturing the prototype. Cabinetmakers' work can be seen as a combination of technology, engineering and crafts at the mercy of mass production. Sometimes the problems emerging are dealt with and solved by using engineering skills and technology with the exception of prototypes, which mostly remain in the hands of craftsmen. Thus, exploring the problem solving situations and its influence on craftsmanship is a first step to uncover the actual skills and knowledge needed in their work.

Matti agreed to share each step of the process and he contacted us whenever he was spending time doing something related to the prototype. However, the documentation was not linear. The beginning was blurred, and Matti agreed to participate in our inquiry about the problem solving not having a clearly directed idea in terms of what the table would look like or what the process would entail. He had different thoughts and used a considerable amount of time drifting between ideas and inspiration. Our documentation was activated once envisioned and finalized the design. In conjunction with the documentation, we attempted to conceptually understand what had occurred during the process. We realized that problem solving situations did not only present itself in specific moments of the process, but that the process itself was a "problem solving" situation.

Moreover, the setting unveiled different types of processes intertwined, not only problem solving. Firstly, a design process that can be preliminarily defined as the process by which "means" are provided to allow the construction of a new object (Kazakçi, 2013). The design process of a table in itself is a problem solving situation, initiated from the unknown and concluding with the product design. Another process intertwined in the documentation was the creative process associated with the creation of the table, which we understand as the process of generating new and useful ideas with regard to products, procedures or processes (Amabile, 1988). This process seemed rather evident from the beginning, since the dialogue with Matti made it apparent. He was "creating a table".

In this paper, we aim to shed some light on and open complex ponderations about these intertwined processes. More specifically, we aim to determine what role problem solving processes play in creative and design woodworking processes.

Theoretical frame

From Problem Solving to Design and Creative processes

A problem means to find the way to evolve from a present situation to another desired one without knowing the path (Schoenfeld, 1983, p. 41). At work, problem solving is not planned but emerges from the circumstances and settings (Llorente 1996, p. 99). The settings in a cabinetmaker's workshop were distinctive in the sense that often the problem solving was related or linked to mathematics. Problem solving typically occurred when the cabinetmaker had to construct a jig to execute a concrete action with a tool (Saló i Nevado & Pehkonen, 2018). Jigs are self-made tools adapted to and meant to assist another tool or instrument. In most instances they need to be tailor-made for concrete use within a project (Paavola & Ilonen, 1981). Jigs molded the understanding of the cabinetmakers' problem solving by advocating open-endedness. Open-ended (Becker & Shimada, 1997) or ill-structured problems (Jonassen, 2000) are unrestricted to different solutions and therefore, they promote divergent thinking allowing the performance of the subject within the own range of abilities and experience. According to Jonassen (2000, p. 67) ill-structured problems are often encountered in professional practices, and the solutions to these problems are not predictable or convergent. Moreover, the solutions often require the integration of several content domains.

Wimmer (2016) differentiates between problem solving and task solution. A problem has been defined as the gap between the current stage and the final goal, when the steps to follow are unknown (Schoenfeld, 1983). If the steps are known, the entire situation turns into a task, whereas, if they are unknown, the situation converts to problem-solving (Bodner, 1987). Everyday work at a cabinetmaker's workshop facilitates the problem solving aspect in addition to task designs or so-called routine designing components (Saló i Nevado & Pehkonen, 2018). The requirements of the table design in our study guided us towards a design process where the solving procedures are unknown and thus the cabinetmaker is working on a design problem. Jonassen (2000, p. 75) refers to design problems aimed at producing artefacts and he categorizes them among the most complex and ill-structured problems one can encounter in practice (p. 80). Yet, in design, both divergent and convergent thinking are needed (Lawson, 1997) in addition to intuition (Wimmer, 2016). The design of a new product may or may not be creative. We understand the design process as the process of conceiving and attributing an existing item with new traits, features. The product in this study is a table to be commercialized and therefore, an essential attribute of the table is that the design has to be creative and appealing. Nevertheless, our cabinetmaker straddles two categories, that of craftsman and designer (Risatti, 2007). From a technical perspective, he is a craftsman since he has the ability to create and materialize products by hand through the manipulation of the timber in addition to his experience and knowledge of the wood (see Risatti, 2007; Sennett, 2008). Simultaneously, he may be considered a designer in the light of the fact that he possesses an acute sense of form and shape with the aim of producing multiple units. (Risatti, 2007). The object of our study (i.e. the prototype) is seen as the final artefact for a craftsman; yet, for a designer it is the test model for mass production (see Risatti, 2007; Temeltas, 2017). Physical artefacts as prototypes or mock-ups, also called embodiment by Goldschmidt (2017), help the conceptual and material aspects of the design, making the details visible (see Goel, 1995; Dorta, Pérez & Lesage, 2008; Pei, Campbell & Evans, 2010; Lahti, Kangas, Koponen & Seitamaa-Hakkarainen, 2016). In addition to this, sketches and drawings aid the refinement of ideas, shape, or the proportions of the product in the early stages of the process (see Goel, 1995; Lawson, 1997; Aspelund & Kontzias, 2006; Cross, 2011).

Creativity in our case is a precondition for the table as a product. Without creativity in the design, there is no innovation, which would have an impact on the commercial value of the product (Roy, 1993; Howard, Culley & Dekoninck, 2007, 2008; Wimmer, 2016). Emerging then, from the design of the table as a framework and as a problem solving situation, is the need to examine the whole procedure as a creative process. A select few may use the term creative problem solving; however, we agree with Wimmer that it is redundant by definition (2016, p. 3) since a design is creative if the product is innovative, unique, valuable, novel and appropriate (Lubart, 2001). Creativity may be defined as a multifaceted construct including divergent thinking, problem finding and problem solving, originality and efficacy (Runco & Jaeger, 2012) and yet, there is a need for further research to examine the similarities and differences between creativity and problem solving (Wimmer, 2016). In 1926, Wallas presented a four-step representation of the creative process, but it was not until the second half of the twentieth century, when some interest was shown in discerning its origins and how the process works. Different studies have prioritized different aspects of the phenomenon such as the person, the product, the process or the environment (see Basadur, Pringle, Speranzini & Bacot, 2000; Vidal, 2009; Leikin & Pitta-Pantazi, 2013). This is consistent with the elements of the conceptual model of design by Ralph and Wand (2009, p. 108). With regard to the creative person, the main traits are the promotion of divergent thinking, fluency and flexibility, among other traits (Maslow, 1987). Several studies consider how novelty versus expertise of the designer impacts the level of creativity (Gero & McNeill, 1998; Jaarsveld & Leeuwen, 2005;). The ability of a creative person to be intuitive has also been considered as vital component of the creative process (Boden, 1994; Raami, Mielonen & Keinänen, 2010). Furthermore, Raami (2015) argues that intuitive personal experiences are important for the creative process.

With regards to the creative process per se, there have been many attempts to describe the creative process model (see Howard et al., 2008). For a product to be successful the prerequisites are that it is new, useful and original, as well as innovative (Buchanan & Margolin, 1995). Depending on the how much the creative process and product differ from other existing products, radical creativity is distinguished from incremental creativity (Gilson & Madjar, 2011). Wallas (1926) presented a stage model widely recognized but the model was also equally criticized (for more see Lubart, 2001; Leikin & Pitta-Pantazi, 2013). His model distinguishes between four stages: preparation, incubation, illumination and verification. Guilford (1950) claimed that the Wallas model was cursory by failing to observe the mental operations that take place. He pointed out determinate abilities involved in the process such as sensitivity to the problem, flexibility, the ability to deal with complexity and to evaluate (see Lubart, 2001). Another critic of Wallas' model was directed at its linearity of stages (Patrick, 1937;

Eindhoven & Vinacke, 1952). In addition, Sapp (1992) argued for the existence of an additional stage called creative frustration, which might occur between the incubation and the illumination phases.

Over time, Amabile (1983, 1996) presented a model where the phases of the creative process did not occur in an established order. In her model, the phases were renamed as problem/task identification phase, preparation phase, response generation phase and response validation and communication phase. Amabile's work presents a dilemma since both concepts "problem" and "task" seem to be interchangeable, and as was previously observed, task solving processes are different from problem solving processes. However, she was not the only one, since, for example, Lubart (2001) claimed that the creative process models are also framed in terms of problem solving, where a problem is considered a task to be accomplished. Other reviews of Wallas model examined different sub processes of the creative process and later on, some alternative models to the four-stage model were presented. The model presented by Mumford, Mobley, Uhlman, Reiter-Palmon and Doares (1991) was based on a series of essential processes: problem construction, information encoding, and identification of best fitting categories, combination and reorganization of categories, idea evaluation and implementation of ideas. Howard et al. (2008) summarize that the tendencies have veered from characterizing the creative process as subconscious cognitive to activity-based phases.

Research questions

A previous study regarding everyday tasks at the cabinetmaker's workshop indicated the significance and value of problem solving situations, namely jigs, for the cabinetmakers (Saló i Nevado & Pehkonen, 2018). In this paper, we wanted to follow the process involved with a specific job at the cabinetmaker's workshop, and additionally find out how jigs alter it. Therefore, we were looking for an answer to the following questions. Question 1 is a background question for questions 2 and 3:

1. What is the cabinetmaker's process of designing and creating a table?
2. How do the problem solving situations influence this process, and what is the role of the jigs within the design process?
3. How are the processes of problem solving, design and creative process intertwined?

Methodology

Data Collection

In this study, we apply narrative and descriptive methods for data gathering through interviews, informal conversations and shadowing. We focus on a single cabinetmaker, Matti, reporting his experience and telling the story of the Pekki table in detail (Creswell, 2012). The narrated story follows chronological events focused on Matti's story of a table creation.

Shadowing, as a method, is the process where the researcher closely observes the work of a participant over a period of time (Quinlan, 2008; Blake & Stalberg, 2009, p. 243). Shadowing enabled us to obtain a closer understanding of how, when and why Matti the cabinetmaker acted the way he did in the process of designing and manufacturing the table. Shadowing provided a rich data set about his action patterns, motivation, mood, body language and pace of work. Matti agreed to participate and to commit to the shadowing method while working at his workshop throughout the process of designing a table and particularly, building up the first 1:1 prototype. He was ready to tell his story. Data collection was facilitated in his workshop and in his home. The study had a unique circumstance as one of the authors was familiar with Matti and had known him for twenty years. They shared a distinct bond since they engaged in communal leisure activities. From a research perspective, having a solid insider status due to the familiarity component with the research participant, made the shadowing process and the data collection for the narrative research possible (Creswell, 2012) by guaranteeing access and developing trust.

At the time of the data collection, Matti was 38 years old, had his own workshop and worked as a part-time cabinetmaker. He had over 20 years of experience in the field and constructed tailor-made pieces and chose his customers according to his availability and the amount of work. Matti had vocational training, experience in the labor market, and he was an experienced, respected and skilled cabinetmaker in his field.

For the shadowing purposes Matti consented to call the researcher with a 30 minutes' margin to arrive at the workshop to track every single step of the construction as many times as was needed. It was agreed that the shadowing would be captured by video recording all Matti's steps and asking him to verbalize his thoughts and actions. Occasionally additional detailed explanations of concrete actions was requested. The researcher was allowed to follow all the steps and stages without reservations. Due to the risk that Matti could feel judged and evaluated through the shadowing process, the connection between him and the researcher had to be one of absolute trust (Blake & Stalberg, 2009). We gathered additional information derived from Matti's body language, his state of mind and disposition, his time management as well as his working pace. During the process, Matti had opportunities to share his experience, to explain what he was doing and why, since the researcher was present and constantly incentivizing Matti's reflections. The researcher had to adapt to Matti's working spaces, conditions, needs and his ways of working. At times, the workshop was cold and was filled with wood dust, which made it difficult to breathe and record. The lenses of the camera needed to be constantly wiped clean and the hands of the researcher got cold.

The workshop was located in the basement of an old wooden building with limited space, dim lighting and not so efficient ventilation. The space was approximately 32 square meters and had an adjacent room of 70 square meters, where the band saw was located and bigger pieces or timber were handled. The researcher had to find convenient spots to avoid interfering with Matti's various tasks. Also, the obvious noise of machines affected the recordings and the conversations. Safety measures had to be adhered to and special equipment was required for some of the tasks, such as sanding or cutting wood. Matti provided safety goggles and breathing masks for the dust component. The duration of each session ranged between two and four hours. At the conclusion of each session Matti explained the next steps, so that the researcher would be familiar with the content of the following meeting in order to avoid any possible surprises (see McDonald (2005) – *"Never go in cold").* The researcher also had to become familiar with the basics of the machinery, tools and materials in use. These circumstances created a further discussion to clarify and find common understanding between the researcher and Matti. Almost all the encounters with Matti were videotaped and pictures and notes were taken. We also collected physical data, such as Matti's sketches and drawings. In this way we could ask Matti to recall the situation, to confirm what was happening or to provide further explanations, or to renegotiate the meaning of the story (Creswell, 2012). Considering the fact that Matti and the researcher were constantly alone at the workshop we resorted to obtaining extra information during the fieldwork by asking Matti about the procedures and happenings. This avoided unnecessary awkward silences. Basically, it was a matter of trust. Sometimes, Matti stopped the work to think and the researcher's questions were the only way to access a verbalization about the situation. (Vásquez, Brummans & Groleau, 2012). According to Mc Donald (2005, p. 457) it is a straightforward strategy to obtain access to both the task and the reasoning behind it.

Factors such as time, inconveniences or unexpected turns in the process forced the researcher to make constant decisions that affected the shadowing process. The shadowing process lasted over 17 months while the first prototype was being built. Matti was interviewed twice in addition to the multiple conversations in the workshop. There were three occasions when we were not able to meet Matti at the workshop. In all three occasions, Matti voluntarily documented what he had done by taking pictures. Before the next session commenced, Matti explained the tasks, showed the pictures he had taken and discussed his feelings and impressions. This was a clear sign of the strength of the relationship established between him and the researcher.

The documentation process is still ongoing, since Matti agreed to further share the development and improvements applied to the model, following the first 1:1 prototype. By June 2019, the 18th Pekki table was being produced and some features of the first prototype had been modified.

Data Analysis

First, we were slightly overwhelmed by the amount and the characteristics of the collected data. There were video tapes, field texts, pictures and sketches all illustrating a lineal process in terms of time. We summarized, sorted out and listed all the actions that had taken place and were videotaped in each session. The sessions had been video recorded intermittently, since the action took place in different rooms of the workshop and there were different machines in use, located in different places of the rooms. The researcher moved the camera and focused it on different elements as well as Matti's various actions. A total of ten sessions were concluded, each of them between half an hour to five hours in duration. There were also several non-recorded conversations and hundreds of photographs. The videos were archived, and the pictures renamed when possible with a descriptive word based on what was captured. Some of the pictures were shown to Matti in order for him to recall the situation and to reaffirm the understanding of what was going on. The details in field notes had to conform to Matti's *a posteriori* explanations as well as the video recordings. Thus, in a separate conversation with Matti, a list of all the steps to build the prototype was made and examined. The researcher visited the workshop several times to confirm some of the details from the notes, such as names of tools and uses of jigs and machines. Subsequently and in order to answer research question 1, a preliminary outline of the whole process of constructing the prototype was made based on actions and tasks, where all the steps were placed in chronological order. We organized the photographs based on the steps of the process they illustrated with the help of the field notes and the videos. This was done in order to provide context for the photographs in the broader scheme of the process. This connected us with the second research question, which is addressed based on the help of the photographs and field notes. We were able to determine a series of instances when Matti encountered a problem solving situation. Those were also listed in the outline. This provided a clear idea of the course of action of the process. Thereafter and for the purpose of analysis, the outline was reproduced on a (large) poster and the photographs were printed and placed in chronological order. The idea was to encapsulate everything in a poster and capture the entire process. We color coded the different phases of the process and we labeled the problem solving situations. After that we were able to start our narrative about the creation of the Pekki Table.

Findings & discussion

The pekki table story

The idea to design a unique item

The Pekki table story answers our first research question and begins with Matti getting the idea to create an item with a unique design with a personal meaning attached to it for each customer (Buchanan & Margolin, 1995; Lubart, 2001; Risatti, 2007). He considered those as unavoidable conditions since the cost of a handmade product is usually high compared to the industrial ones. Matti explained that the engine of this project was the fact that most of the timber produced in people's yards and lands are mostly used as burning wood. When these trees must be felled for some reason, Matti thought that by transforming the timber into something new and useful, instead of burning wood was a good alternative for the customer. Amabile (1983) referred to this phase as problem identification phase and for Wallas this was the preparation stage (1926). Trees stand for decades in the same spot on a land and often, they become landmarks attributed to memories of past events or generations. Matti considered a piece of furniture and his mind started to wander around the idea of a table, where a family spends time and gathers around to eat dinner. He had experience building kitchens and realized that kitchens had too many intrusions - as he called them - he would have to cooperate with other professionals and make too many compromises. In addition to this, his prerequisite was for the item to be ecological, and a kitchen was not. At this moment, the idea of designing a table was born. However, Matti did not have a clear vision in terms of the look and design of the table. This was the prologue of the story. Matti acknowledged the "want to create something taking into consideration the different conditions and factors" which Jonassen (2000) would refer to as the integration of different content domains. This 'something' became a table. It was also the first time we got to know about this project, and it was then that Matti was asked to share his thoughts for documentation purposes. Matti accepted.

Thinking about "how is the table going to be"

Matti thought about several ways of what he wanted the table to look like. He drew sketches (e.g. Lawson, 1997; Goel, 1995; Aspelund & Kontzias, 2006; Cross, 2011) and made some approximate calculations of the possible measures of the table. However, he was not convinced. He had explained his ideas to other colleagues and friends, exchanged some views and was left with his thoughts. Time passed by pondering over the lines and shapes of each of the pieces, including both conscious, unconscious thinking and intuition, which made it vague to follow and difficult for Matti to share (Jonassen, 2000). This part could be regarded as the incubation stage of Wallas (1926) and the preparation phase for Amabile (1983). However, even if most of the explaining was done subsequent to the cognitive work, the embodiment via sketches and drawings was present. This made this period fuzzy and vague in terms of documentation (Guilford, 1950) as Matti discussed part of his thoughts and showed some sketches; but the certainty of all details remained hidden inside his head. There is no way to follow someone else's own private thoughts and divagations over a topic, let alone over a not yet formed idea for a long period of time. Most of the sharing was done *a posteriori*, when Matti's divagations were over, and when he was able to verbalize his thoughts. Matti kept drawing and sketching which helped him clear up his thoughts and ideas. This part of the story was regarded as the search for the right-fitted image of the dream product, the idea generation of the desired artefact (e.g. Dorta et al., 2008; Lahti et al. 2016; Goldschmidt, 2017). Matti claimed that he was not satisfied with just a mere idea of what he wanted (the final product) but he needed to feel that *"that is the one, the one that feels right"*. This part of the story was least accessible for the researchers. Problem solving processes per se were not detected. However, Matti used progress elements that are typically regarded as problem solving strategies; such as defining the limit of what he was looking for, considering the pros and cons of the product features, drawing pictures, trial and error, working it backwards, generation of solutions and use of objects to simulate. Some of these elements are also present as tools in the design process (see e.g. Aspelund & Kontzias, 2006; Dorta et al., 2007; Pei et al., 2010;)

Envisioning the table

Frustration with the process emerged for the first time after some months. Matti claimed that he encountered the need to have a break and rest from the continuous search for the right idea (see Sapp, 1992). He was fatigued due to his everyday job and the normal stress of everyday life, and needed a holiday, therefore, a family trip to Japan ensued. Detached from his daily routines and everyday tasks, he suddenly had a clear idea of what he wanted, and it felt good. He envisioned the table, its main features and lines. He reported as soon as he came back from Japan that he *"knew what the table would look like, the lines, the features"*. He said that he could see it. Wallas (1926) regarded this period as the illumination stage and Amabile (1983) labeled it as the response generation. We consider this the turning point in our documentation process. This stage opened the door to the 'real' game: the envisioned table started as a visualization and now Matti could sketch it in more detail and share it with the researcher. This period was free from problem solving, as if the greatness of the finding erased considerations over possible issues with the execution. These possible problems were to appear in the stage that followed.

Constructing the first prototype

Constructing the first prototype was not apparent or swift. It meant the embodiment and execution of what was just a visualization, an idea combined with a few sketches. This was the time where his abstract idea became concrete and was materialized, which Amabile (1983) regarded as response validation stage and Wallas identified as verification stage (1926). The table - now named as Pekki - was literally being created. For Matti, what had been a vision complemented and developed in the form of sketches and drawings was going to be un-built piece by piece, and reconstructed in wood. Matti first did a 1:10 model to materialize the idea. It resembled a sauna bench rather than a table, but Matti found the lines and proportions pleasant. This scale model was made out of solid wood, without dovetail joints and, instead, with domino oval pieces. He was satisfied with it, but he was not sure of how the legs and joints would be in a 1:1 scale model. The materialization helped the development of the process (Lahti et al., 2016) and afterwards, Matti had to fabricate a scaled 1:1 prototype of the envisioned table to see if the proportions and look of his idea were right. We documented this process in real time.

Initially building a prototype seemed as an extra step. The ‘glory’ of the Pekki table remained in the enlightenment where the idea appeared. However, the relevance of the prototype construction was massive, as it translated into an evaluation of the feasibility of the outcome (Howard et al., 2008; Dorta et al., 2008; Cross, 2011).

Photo I. Matti preparing timber to be used for a Pekki table.

Matti used regular timber bought from a nearby wood supplier for building the first prototype. He explained that for a real unit, the timber should come from a tree with some sort of connection to the customer. For the prototype, he needed to see the behavior of the wood, and therefore the timber used had to be reasonably easy to manage and strong enough to tender a good quality result, as a prototype would be the sample unit for further business opportunities (Temeltas, 2017; Risatti, 2007). Matti prepared the timber, soothed and squared edges for the top of the table (Photo I). He trimmed the sides of the log, cut it in half and diagonally split it. He had to come up with three different jigs to assist with the job (A, B and C, see Table 1). Matti needed the jigs in order to accurately use the band saw (see Paavola & Ilonen, 1981; Saló i Nevado & Pehkonen, 2018). He measured the diagonals of the planks and cut exact pieces. Then he measured the width and planed the wood. After that, he needed another jig (D) to measure the thickness and plane the timber again. The last operation was to measure the length and cut the end with the circular saw. At this point, Matti ended with four timber pieces to make the top of the table ready for the next adjustments. Matti made modifications and amendments to the top of the table planks and glued them two by two. The same jigs (A, B, and C) were used for slanting the ending of the glued pieces. He proceeded to put together all four boards to form the final top of the table using one more jig (H). Once the top was glued together, he made the hole for the dovetail joints of the legs (Photo II). He milled the timber and routed a 7-degree angle socket. This operation was the most demanding one in terms of jigs. He constructed one more jig for that purpose (I).

Photo II: a router and jig I to make a 7-degree angle socket for the dovetail joints.

Photo III: the top planks glued together

At the end of this phase, he sanded the top of the table. Matti repeated the same operations as with the table top planks but with different measurements. He trimmed the sides of the log, cut it in half and diagonally split it. He used the same jigs as the table top but with a different angle (A, B, C and D). He pitched the legs with the help of another jig (J) and cut the dovetails for each of the joints of the legs with the aid of jig K. Before polishing the legs, Matti cut the endings to stabilize the table when in standing position. At that point Matti had all the different parts of the table ready i.e. the table top and the legs. He assigned a number to the table (Pekki 0) and marked it with a burner inside one of the dovetail holes of the table top. However, when Matti assembled the table, the legs felt too heavy. He was disappointed and claimed that they looked like massive *"elephant legs"*. He then started to plan and make holes with chisels on the legs to try to lighten the appearance. He did a lot of sanding and soon the legs started to look like *"an animal bone"*. He took the router and made the outside edgy curves round with a quarter round blade. Now Matti was pleased. The prototype, which had helped Matti to make the final refinements (Cross, 2011), was ready. The *Pekki table* was born.

The name Pekki came from a stream that passes beside Matti's workshop. A stream is called *puro* in Finnish and *bäck* in Swedish. In the olden times, Finns called it *Pekki*, shaping the Swedish word into a more Finnish-like sound. Matti liked the named since it reminded him of something sturdy, made of wood, like a bench (*penkki* in Finnish language).

Prototype versus Pekki table final model

In line with several studies related to the design process (see Aspelund & Kontzias, 2006; Dorta et al., 2008; Cross, 2011), the final model of Pekki Table (Photo IV) was developed based on the prototype. There were three substantial differences. First, in the prototype the bottom of the table top was slanted from the ends towards the center, but not in the final models of the Pekki table. Secondly, the top planks had a four-millimeter space between them in the final model (see Photo III). He drilled holes for the dowel joints that later would connect the planks. He cut the dowels in octagonal shape, sanded the endings and glued the dowels to one of the sides of the planks. These operations needed three different extra jigs (E, F and G). In the prototype model the top planks were glued together. The third difference was the round shapes. In the prototype all the edges were rounded as opposed to the final model were all the edges are sharp.

Photo IV: The final model of Pekki table, photograph by Jonna Öhrnberg.

Problem solving, design and creative processes

In terms of answering our research question 2, throughout the process of building the prototype, Matti did numerous routine jobs such as cutting, sanding, measuring, gluing, etc. Simultaneously, he encountered several problems when intending to carry out those tasks because of the measurements or the slant of the timber. It became obvious that some situations interfered with the pace of the work and most of these drawbacks corresponded to moments when Matti had to create jigs (Saló i Nevado & Pehkonen, 2018). Although problem solving and creative processes share many similarities, we do not consider creating jigs as a creative process. We consider jigs in the first place as problem solving emerging from the professional practice (Llorente, 1996). Jigs are meant to serve definite purposes, and their value is in feasibility and practicality, not in novelty or exterior design (see Saló i Nevado & Pehkonen, 2018). Problem solving is not a uniform activity nor were the jigs Matti used, but each of them conditioned the existence and possibility of the Pekki table (Jonassen, 2000). The eight jigs that Matti used for the prototype construction are presented in the first column of Table 1. Jigs E, F and G are not included, since they were not used in the prototype construction.

All the jigs used by Matti had a common denominator: time. The difficulty level of the jigs' directly influenced how much time Matti used to find a solution. The first jigs (A, B, C and D) were easy for Matti as an experienced cabinetmaker, whereas some jigs (for example I and K) were more complicated and demanded more time to construct. Jigs A, B, C and D are examples of what Jonassen refers to as ill-structured problems that had become well-structured with practice (2000, p. 67). The mathematics embedded in jigs I and K were related to angles of inclination and trigonometry (Photo II). Matti did not use trigonometry to solve and find solutions for the jigs. At some point he mentioned that most likely, using trigonometry to calculate the angle he was looking for would have been easier and faster, if the mathematical procedures were ready in mind. However, the materialization of the mathematical knowledge was the part that became the most time consuming. Hence, he discovered by trial and error that each side of the wedged dovetail needed to be increased by 4-degrees to enable the tightening of the elements (mortice and dovetail).

Success in building each of the eight jigs' was translated to the process of the Pekki table construction, in the form of progress. Each of the jigs worked as a key to the next step in the process, like a door. In the Pekki table prototype construction, the jigs order, in terms of the production of each of the pieces, mattered. However, some of the jigs had to be used more than once and that meant that there was no need to build a new one, but to apply the existent ones and modify the adjustments to obtain specific measurements. This is the case of jigs A, B, C and D, which had to be used for both cutting the timber for the top of the table and for the legs.

Seven jigs out of eight had a clear influence on the precision of certain stages of work. The three first jigs (A, B, C) were made to assist the band saw and to allow precision to the cuts made to obtain the exact length, width and slant in the planks. Jig D was used to assist the thicknesser planer in obtaining the right thickness of the wood. Matti did not consider these jigs as complicated. Jonassen (2000, p. 69) would call them routine problems since they were familiar to Matti as an experienced cabinetmaker. Matti only needed to care about the exact measurements and positioning of the timber to obtain the right cuts. Also Jig H, exerted the right pressure and maintained the timber in the right position to be compressed and glued correctly. These first 5 jigs required mathematical precision to be a success and, therefore, they were technical and problem situated, falling into the category of diagnosis-solution problems (Jonassen, 2000, p. 75). There was no room for considering whether these jigs looked good or their design was groundbreaking. Their influence on the process of creation of the Pekki table was related to precision and since those timber pieces were the base of the project, a perfect functionality of the jig was required. The fact that these problem solving situations were successful, does not automatically regard their novelty as a creative trait. This is in contrast to Wimmer's statement that "successful problem solving can be regarded as creative process" (2016, p. 3). Jigs I and K were meant to assist the router to making a socket with a certain incline for the mortice and the dovetail (Photo II). Both jigs required a more advanced level of mathematical knowledge and Matti did not have any previous expertise (see Raami, 2015). The mortice and the dovetail needed a 7-degree angle to match each other and the shape of the mortice was complex since it was a truncated and rounded wedge with a leading edge opening to the trailing base of 4-degrees per side from the truncated corners.

To answer question 2, the problem solving situations emerged during the creation of the Pekki table influenced the process in terms of time, precision and progress. The problem solving situations created drawbacks, were time consuming and interfered with the pace of work. The perfect functionality of the jigs allowed precision in the cuts and the different parts of the table, and success translated into progress within the Pekki table process.

The intertwiness of processes

In order to understand the interconnectedness between processes and to answer the third research question, we took each problem solving situation (jigs) under consideration. We looked at what happened in each of them in terms of design and creative processes and also at why and for what purposes the jig was needed. In fact, we noticed that all problem solving situations consisted of a set of three smaller problems. Firstly, how to proceed (how to saw, how to cut, how to glue…); secondly, what jig is needed to proceed within the construction process and thirdly, how the jig is constructed. Jigs, as tools, are the solutions. Table 1 describes the jigs and their connections to the creative process, the design process and the construction of the prototype process.

Table 1. The problems solving situations and their influence on the creative process, the design process and the construction of the prototype process.

PROBLEM SOLVING SITUATIONS (PSS) = JIGS	CREATIVE PROCESS	DESIGN PROCESS	CONSTRUCTION PROCESS
JIG A: assisting jig for trimming timber ends.	No special influence (NSI) in terms of creative process.	NSI	The cuts are needed in any case for any type of table. Needed for the measurement precision.
JIG B: assisting jig cutting the timber in half to get two planks.	NSI	NSI	Relevant for proceeding with the construction of the table. Needed for the measurement precision.
JIG C: assisting jig in diagonally splitting the planks for the top of the table.	Mattis's mental idea about the visual lines of the table top.	First jig with clear influence on the design process. This jig allowed Matti to confer to the top of the table an original trait. The inclination of the bottom of the table top. Without the jig, the cut could only be perpendicular to the base instead of diagonal. The diagonal conferred the desired visual effect. Distinctive design.	Relevant for proceeding with the construction of the table.
JIG D: assisting jig for holding the timber when using the thicknesser planer for measuring and planning the precise plank thickness.	NSI	NSI	Relevant for proceeding with the construction of the table. Needed for the thickness precision.
JIG H: assembling jig for holding the top planks together until the glue is dry. (Photo III)	NSI	NSI	Relevant for proceeding with the construction of the table.
JIG I: guiding jig for the router to obtain the exact desired mortice shape on the bottom surface of the top of the table routing a 7-degre angle socket for the dovetail joints with a distinctive precise shape: truncated and rounded wedge shaped with a leading edge opening to the trailing base of 4-degrees per side. (Photo II)	Matti's mental, innovative idea about the tightening system of the table and the joints of the legs.	Influence on the design. This jig allowed Matti to obtain the precise mortice shape. The shape that the jig permits the router to make will let the legs to be connected without joints, nails or glue by exercising friction and tightening the leg to the table top. This is one of the innovative design traits of the Pekki table.	Relevant for proceeding with the construction of the table.

JIG J: subjecting and guiding jig for the manual leg pitching. The jig secured the timber to be able to use planers and sanding paper to give the right slant to the legs of the table.	Matti's mental idea of the visual lines of the legs.	Influence on the design process as this jig permits the visual effects that Matti wanted to obtain on the legs of the table. This jig conceded the handwork of the cabinetmaker on the timber piece.	Relevant for proceeding with the construction of the table.
JIG K: guiding jig for the router to make a dovetail in each leg. Complementary jig to jig I. The jig guides the router to obtain the exact desired dovetail shape at the end of each of the legs.	Matti's mental idea about the tightening system of the table and the joints of the legs	Influence on the design. This jig allowed Matti to obtain the precise dovetail shape. The shape that the jig permits the router to make will let the legs mortice to be connected without screws, nails or glue by exercising friction and tightening the legs and the table top. This is an innovative design trait of the Pekki table. The legs are detachable.	Relevant for proceeding with the construction of the table.

As shown in Table 1 four of the eight jigs that Matti used had no influence on the design process of the Pekki Table. Those jigs (A, B, D and H) assisted the stages of the job that were needed for the construction of any type of table and had no innovative component and therefore routine design (Howard et al., 2008). However, as shown above, each of them contributed to the construction process through the precision of the item and its features, the progress of the processes, and on time consumed. The four remaining jigs had a clear influence on the design processes of the Pekki table (shaded cells in Table 1).

Matti's endeavor was to define the traits and lines of the table so they would become different, attractive and functional and therefore a new design (Risatti, 2007). The creativity of the process of the Pekki table design was directly connected to those new traits, and hence, the moments when those traits were made possible in the design process, they were meaningful (Risatti, 2007; Temeltas, 2017). The three design traits that defined the Pekki table as a new design, were the slanted bottom surface of the top of the table, the absence of nails, screws or glue in the joints (which allowed the table to have detachable legs), and the tightening system facilitated by friction (not just stuck on and attached by force). These made the Pekki table portable and possible to assemble at any given time. With the help of jig C, Matti was able to split the planks diagonally – as he wanted – for the top. Jigs I, J and K solved the problem allowing for a new design, thus making the design innovative. In particular, the friction exercised by the correct angle of inclination of the inner wall of the mortice and the dovetail made the tightening strong and firm. So, the design traits Matti had dreamed of was made possible.

Our analysis shows that problem solving processes are mediating processes between creative and design processes. Referring to the model of Wallas (1926), the design process can be seen to take its position between illumination and verification phases of the creative process. In the design process, Matti's illuminated, ideated and partly visualized ideals were verified and realized. Problem solving assisted in gradually making it possible.

Concluding remarks

A creative process ends in a new idea, something novel and original. In the case of the Pekki table, at the beginning of the process, Matti wanted to create "something new", innovative. Therefore, the process was regarded as a creative process, which started when Matti realized that he wanted to create something. This was a problem solving situation in itself as there was a gap between the moment Matti knew that he wanted to "create" something and when the "created object materialized". Wimmer (2016) regards a problem situation as a necessary condition for a creative process to occur. In our case problem solving and creative processes are parallel to each other. This is what we have argued previously (Saló i Nevado & Pehkonen, 2018). At the same time, the instant when Matti could visualize and decide that his creation was going to be a table, the creative process became parallel to a new design process, since a table is an artefact from a category that already exists.

Our data indicated that the creativity of the problem solving solution, i.e. the level of creativity of the jigs, was not relevant at all for Matti. Instead, the success of the outcome of the problem solving situation (i.e. the jigs), had influence on the creative traits of the table and direct impact on the design. Matti's jigs could be considered by definition as open-ended problems, or ill-structured problems as they were open to many different solutions (Becker & Shimada, 1997; Jonassen, 2000), and they mediated between the process of creation and the design of a table.

Our findings are based on very specific data in a specific woodworking context. Further research must be pursued in different vocational fields to obtain a deeper understanding about the connections between problem solving at work, design and creativity.

Without Matti's commitment and enthusiasm, writing this paper would not have been possible. In this study, Matti was not a mere informant or subject under observation. Rather, he was our active partner, who dedicated himself to our project in a unique way. He not only shared the entire Pekki Table creation process and his thoughts with us, but also revised and commented on our text. Matti checked and verified that what he had thought and done during the process was noted and understood correctly. In terms of validity this has been extremely valuable.

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