Understanding the Creative Mechanisms of Design Thinking: An Evolutionary Approach

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ABSTRACT

In this article, we analyse the concept of design thinking with its process, the team structure, the work environment, the specific culture, and certain brainstorming rules and techniques. The goal of this work is to understand how the creative mechanisms of design thinking work and how they might be improved. For this purpose, we refer to the idea of creativity as an evolutionary process, which is determined by generation (i.e., recombination and mutation), selection, and retention of ideas. We evaluate the design thinking process in terms of its capabilities to activate these mechanisms, and we propose possible improvements. This paper contributes to a better understanding of creative design processes in general and the design thinking process in particular, and will serve as a foundation for further research about creative mechanisms.

Keywords

design thinking; evolutionary creativity; innovation methods; creative education

INTRODUCTION

Although there exists a substantial amount of literature about the working mechanisms of creative design processes in general and about the evolutionary theory of creativity in particular, no detailed analysis of creativity in the design thinking process has been conducted thus far. Design thinking [4] is a specific design process that has become more and more popular among companies around the world and is being implemented into the curricula of engineering and business schools [16]. The aim of design thinking is to foster innovation by generating concepts for new products, services, or digital applications, and to develop solutions to so-called wicked problems [5, 37].

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Since generating creative concepts is one of the core aims of design thinking, we try to analyse how this is actually achieved. The first part of this article presents a short overview of the design thinking process, as well as the involved artefacts and team members, and the underlying principles and guidelines for the process. In the second section, we present an overview of the evolutionary theory of creativity. Both sections also cover the analysis of existing literature in each area. The third section describes the used methodology, while in the fourth section, the main part of this article, we draw a comparison between the two concepts by mapping the evolutionary theory of creativity to design thinking. Here, we do not only refer to the design thinking process itself, but also to the role of the work environment, involved and created artefacts, the role of teams, the importance of a specific design thinking culture, and a set of rules and rituals. Finally, we conclude by providing a summary and an outlook to further research.

DESIGN THINKING

Design thinking, originally introduced and shaped by the design consultancy IDEO [27], is a specific design methodology with the aim of fostering creativity. Brown [4] provides the following definition of design thinking: "Design thinking can be described as a discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity."

The following aspects and principles are meant to support the creative process in design thinking: a) the design thinking process itself with its different process steps and ideation techniques, b) a multidisciplinary composition of teams, c) the setting of the work environment, such as the work space and certain involved and produced artefacts, and d) the specific culture and atmosphere. Although these elements are crucial to every design thinking project, they might differ among institutions or companies. In this article, the focus is on the design thinking process in an educational context, as it is practiced at the HPI D-School (see Figure 1).

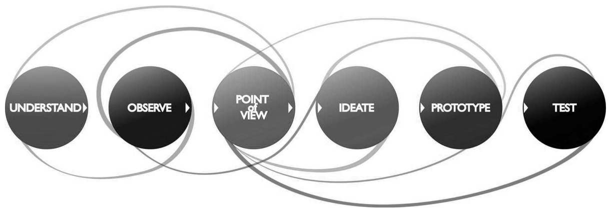

Figure 1: The design thinking process at HPI D-School [34] (used with permission from HPI Potsdam, Germany)

In this model the design thinking process consists of six steps, which are visually connected by curved lines to indicate that these steps can and should be performed in iterative loops, if it appears necessary to go back to a previous step. This model is quite rough and bears resemblance to the typical design process as it is known in the design community since decades. The concept of design thinking, however, is to transfer designerly methods, tools, and processes to other areas. Even if these elements are well-known and well-established in the design area for years, still, there are several aspects in design thinking that are usually not covered in classical design. Specifically, design thinking focuses on solving wicked problems [37], and is not limited to classical design problems (such as designing an ergonomic chair). Moreover, the participants in design thinking projects are multi-disciplinary and not designers only. Design thinking uses a certain design methodology with tools and processes that have been made explicit and available for non-designers. However, this is not supposed to mean, that anybody can be a designer. The scope of design thinking is different: Since it is the main goal of design thinking to create innovations (instead of classical three-dimensional design), it involves designers with their unique skills, but also experts from other disciplines—working together on projects that aim at creating innovative solutions to wicked problems. Those characteristics of design thinking are not visible in the process model provided by the HPI D-School (Fig. 1), since it is not showing the multi-disciplinary approach nor is it describing what is actually happening in each respective step of the process. Thoring & Müller [42] suggest a more detailed model of the design thinking process that describes what is actually happening in each of the six steps. We provide a short summary, here.

While in the first step, *Understand*, existing information about the topic is gathered through secondary research, the second step, *Observe*, is based on a qualitative research approach that includes interviewing and observing techniques. The goal of this step is to collect insights about problems and the users' needs, of which they are usually unaware but must be identified by the design thinker. These insights are then shared among the group through storytelling and then synthesized into a visual framework called *Point of View* (POV), which is like a microtheory about the problem and reflects the user's perspective (could be a persona, a mind map, a two-axes-matrix, a Venn diagram, a causal graph, etc.). Next, the *Ideation* phase begins with creating a brainstorming question related to the Point of View. After the team brainstorming is complete, the best ideas are selected by team voting. During *Prototyping*, the selected idea is built very quickly; e.g., with Legos, cardboard, or existing objects; by paper-prototyping (for digital applications); or performed as a role-play (for service concepts). Finally, in the *Test* phase, the prototype is taken back to the users to gather feedback on the concept. Issues revealed during testing are then fixed in one or more iteration loops in which either the prototype is revised or the whole concept is reconsidered. In some cases, it might even be necessary to go back to the research phase (steps 1 and 2 of the process) to gather more insights or to interview different target groups [42].

Besides the design thinking process, there are several more aspects in design thinking that add to the effectiveness of the process, such as the team constellation. Design thinkers should be so-called 'T-shaped' people, which means that they have a strong expertise in one area (the vertical bar of the T), but at the same time they have a broader knowledge in neighbouring fields and strong communication skills (the horizontal bar of the T). This enables them to connect to other design thinkers. An ideal team consists of five to six people with different backgrounds. For instance, teams could include one designer, one technical engineer, one software engineer, one businessperson, and one person related to social sciences or psychology. One of the D-School mindsets is called "teach teams with teams", which means that in this educational context, the design thinking student team is supervised and guided by a team of teachers who also have different backgrounds.

The specific design thinking work environment and equipment—furniture (whiteboards, tables, and sofas) that are on wheels to be moveable and flexible—are also an integral part of the design thinking process. Additionally, there are certain artefacts that support the design thinking process, such as a 'Time Timer', which counts the time backwards and indicates the amount of time left in a particular phase (such as the brainstorming). The substantial use of Post-it notes to capture insights from the research or ideas, which are stuck to whiteboards and allow easy rearrangement, provide organizational support for the process. For inspiration, there is a D-School library with related books and a shelf with boxes containing different materials for prototyping, such as Legos, cardboard, pipe cleaners, etc. See Figure 2 for examples.

Figure 2: Examples of the D-School equipment: Time-Timer, Post-it notes, moveable furniture, bookshelf, boxes with materials

The specific D-School culture is also integral to the design thinking process. Each day starts with a warm-up exercise to enforce team spirit. At the end of each day there is an 'I like, I wish' session, which gives every participant the opportunity to critique or to suggest improvements to the process. Additionally, the whole atmosphere at the HPI D-School is determined by playfulness. A music station in every work space, free drinks, regular get-togethers, and many toys and games on hand enhance the creative spirit. The entire approach is guided by some work principles or mindsets, such as "think user-centric" and "fail early and often".

Rules and brainstorming techniques are another essential component to the design thinking process. Of course, there are also rules that are immanent to almost every kind of ideation technique, such as brainstorming rules. In design thinking, there are usually seven brainstorming rules, which include "be visual", "defer judgement", "build on the ideas of others", "stay focused on topic", "one conversation at a time", "encourage wild ideas", and "go for quantity" [27]. Specific creativity techniques are also used from time to time. Two examples are 'negative brainstorming', in which only 'bad' ideas that make the problem even worse are to be generated and then reverted to create a positive solution, and the 'dark horse', in which one of the wild ideas is developed and prototyped.

In the main section of this article, we describe all of these aspects in more detail and present our assumptions about their possible influences on the capability to foster creativity. We also offer suggestions on how the whole design thinking process could be improved based on some deficits that we have identified.

EVOLUTIONARY THEORY OF CREATIVITY

Since design thinking is usually performed by a team of diverse people, instead of a single 'genius' designer, the whole concept of evolutionary creativity seems to be interesting for analysing the creative mechanisms of design thinking. Evolutionary creativity is well established as an analysing framework for the evolution of ideas and theories [6, 7, 18-21, 25, 35, 36, 38-40]. It can explain creativity not only in one person, but is also able to explain and describe creativity in teams and systems. Therefore we adhere with this concept and will later use it to analyse design thinking in terms of its capability to foster creativity.

The theory of universal Darwinism [14] claims that the evolutionary theory [12] is applicable not only to biological species, but also to all complex systems that have the characteristics of variation (or generation), selection, and retention. Several streams of research apply evolutionary ideas to nonbiological fields. According to *Memetics*, the evolution of mental ideas can also be defined through the evolutionary theory [13]. Hereby, *memes*, which are analogous to genes, represent the mental or cultural content. Memes are hosted in human minds, replicate from one mind to another, and compete with other memes. The evolutionary theory of economics tries to understand innovations and economic growth by Darwinian concepts [31]. Evolutionary epistemology explains the growth of scientific knowledge with evolutionary concepts [7, 35]. In computer science, evolutionary algorithms try to mimic the evolutionary process with software for diverse optimization problems [23].

In this paper, we use the evolutionary theory of creativity [6, 19, 21, 38, 40], which compares the creative processes with the biological evolutionary model [12].

In all these evolutionary theories, the three steps—generation, selection, and retention—are crucial. The working mechanisms for these three steps can be very different between fields:

1) Retention. A pattern of information is stored and reproduced. In biological evolution this is accomplished by inheritance and breeding. In the creative process, ideas are retained, either in the mind, written down, or otherwise captured, and communicated.

2) Generation. There are two mechanisms that can produce variation, and thus generation, in the stored pattern: mutation and recombination. In biological evolution, this is achieved by genetic mutation or genetic recombination (by chromosomal crossover). In a creative process, new ideas can also be generated by idea mutation and idea recombination.

3) Selection. There are some selection mechanisms that test the performance or fitness of the pattern in a context. In biological evolution, this is done by natural selection on the phenotype, as well as by sexual selection. In idea evolution, this happens through idea selection and idea testing.

In biology, the genotype is the genetic information of a creature (DNA), while the phenotype is the actual representation: the animal. Analogously, an idea in the creative process can be described as the genotype, and some instantiation of the idea, like a prototype, can be described as the phenotype.

In literature about evolutionary theory of creativity, two different evolutionary models were distinguished: Darwinian and Lamarckian evolution [6, 20, 28, 38]. The Darwinian evolutionary model can be described as "blind variation and selective retention" [6]. That means that the variations are 'blind' for anticipated results. Also, learnings from the phenotypes will not be stored (inherited) in the genotype. In the Lamarckian model, however, learnings of the phenotype are supposed to be passed on to the next genotype. The evolutionary process can be seen as one heuristic optimization strategy that tries to find a (global) optimum in a very large solution space (see Figure 3). This evolutionary optimization is less likely to be stuck in local optima than other heuristic methods like greedy ('hill-climbing') methods [23]. This can be explained by the fact that evolution is not always a linear, smooth process but can include 'jumps'. These so called 'punctuated equilibria' [17] can help to break out of a stable local maximum.

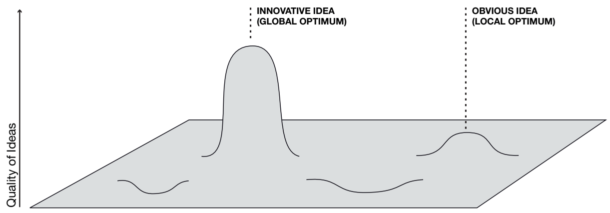

Figure 3: Optimization problem with a large solution space

METHODOLOGY

Our article is mainly based on case studies from the HPI School of Design Thinking at the Hasso-Plattner-Institute in Potsdam, Germany (HPI D-School). We map these observations to the theory of evolutionary creativity and condense them into a theory about the working mechanisms of the design thinking process in terms of its capability to foster creativity. Therefore, this work can be considered as a theory for analysing (Type I theory) according to Gregor [22].

Over a period of three years, we observed five student projects of different lengths in a design thinking education context and analyzed them in terms of their creative outcome. Specifically, we observed how patterns were memorized (retention), how ideas were created (generation), and how ideas were selected (selection) among the student teams.

Selection of Cases

We chose five specific projects for our case study (see Table 1), according to the following criteria: 1) experience of the students, 2) involvement of industry partner institutions, and 3) diversity of the design challenges. The selected cases were scheduled at an advanced stage of the study program, when the students already had some experiences with short design thinking exercises. The selected 6-weeks projects were scheduled at the end of the first semester, and the 12-weeks project were taking place over the entire second semester. Both types of projects had external project partners involved who acted as some kind of client. This realistic setting allowed for a better analysis of the role of knowledge than mere test exercises. And finally, the selected cases were representing a broad diversity, both in scope, cooperation partners, and also in the results (partners were NGOs as well as industry corporations, or governmental institutions; results ranged from physical products to digital applications). This diversity suggests that specific observations concerning the creative output were independent from project topics or scopes. All projects were conducted by a team of 5 to 6 students. The 6-week projects were conducted by two teams who worked simultaneously on the same challenge in a competitive manner. This provided the possibility to crosscheck the observed results. We analyzed 5 projects conducted by 8 different teams (see Table 1).

Case	Challenge	Dur. #	Industry Partner
1 People Trusting People	How might we establish trust between friends in lending situations?	12 weeks 1 team	Telekom Germany (Industry)
2 Airport Security	How might we assure the security standards at passenger airports and increase efficiency and convenience of passenger handling during check-in?	12 weeks 1 team	ZAB (Gov.)
3 Empowering Participatory Politics	How might we help inexperienced internet users to make meaningful contributions to political debates and processes?	6 weeks 2 teams	Res Publica (NGO)
4 Modern Office Communication	How might we design an office system to handle mail management processes that facilitates the every day communication activities of office employees?	6 weeks 2 teams	Francotyp Postalia (Industry)
5 Book Recom-mendations	How might we help readers to discover those 50 personally relevant book releases each year?	6 weeks 2 teams	Elstner-tainment + WDR (Industry)

Table 1. Overview of selected Cases

Data Sources

For each step of the design thinking process, the following data sources were observed and analyzed: the behavior of individual team members as well as interactions within the team (group and teambuilding activities), verbal expressions, written output (such as ideas on post-it notes or texts in the project wiki), visual output (such as diagrams, sketches, photos etc.), prototypes, and the use of the environment (such as whiteboards or post-it notes) as knowledge repositories, etc.

Research Procedure

We conducted the case study based on two independent data analysis methods: one researcher acted as a coach and was therefore involved in the project and was able to extract first hand insights from the team (participatory observation). The second researcher acted as an external (independent) observer. He checked the results afterwards and was therefore able to act as verification. Any possible bias caused by the involvement of the first researcher could therefore be compensated to some extend. This research procedure was split and cross applied: one researcher was the main teacher for one half of the projects and additionally acted as an external observer for the remaining projects, and vice versa.

ANALYSIS OF DESIGN THINKING ACCORDING TO EVOLUTIONARY THEORIES OF CREATIVITY

In this section, we present a comparison of certain aspects of design thinking as described in the first section and align those with the three main concepts of the evolutionary theory of creativity (generation, selection, and retention of ideas) as described before. We then discuss the possible impact of the design thinking mechanisms on the creative outcome.

Design Thinking Process Steps

Brown [3] describes design thinking as the sequence of the diverging and converging of solutions. In the diverging phase, choices are created, while in the converging phase, choices are made (see Figure 4). This phenomenon is also described, for example, in Plattner, Meinel, and Leifer [33].

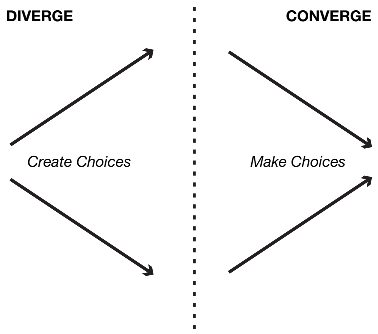

Figure 4: Diverging and converging in design thinking, adapted from Brown [3].

Comparing this image with the concept of evolutionary creativity, we consider diverging as a generation of ideas (creating choices) and converging as a selection of ideas (making choices). If we look at the design thinking process as a whole, we can see that there is actually a constant alternation of generation and selection of ideas. We call this the possibility space (see Figure 5).

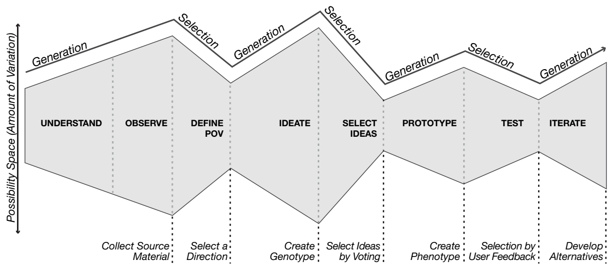

Figure 5: Alternation of generating and selecting in the design thinking process.

In the first two steps of the process (Understand and Observe), information and insights that can later be used as a source material for mutation and recombination are gathered. Ideas rarely emerge from nowhere. As in nature, a substantial amount of source material (background knowledge, insights, and experiences) is necessary in order to enable the generation of ideas. The possibility space is expanded, which means that as many options as possible are opened up.

In the Point of View step, the possibility space is reduced again. The insights from the research are condensed into a formal problem statement that determines the future focus of the project.

In the Ideation phase, ideas concerning this problem are generated by recombination and mutation of the previous insights, usually in the form of a brainstorming session. This is actually the 'creative' step in which the ideas are produced and the possibility space is expanded again. Part of ideation is also the selection of those ideas that seem to have the most potential. In design thinking, this usually happens through a vote by all team members. The team decides on a few ideas to be developed further. Sticking to the evolution metaphor, this type of voting for ideas can be considered a kind of 'artificial' selection. The idea at this stage can be compared with the genotype in biology; in other words, it is the DNA of a possible solution. Voting reduces the possibility space again and focuses on specific solutions. Those solutions are then visualized in the prototyping phase. A prototype can be e.g. a physical model, a photo story, a role-play, or a video. The possibility space is then opened up again (even if only slightly), since the team is now considering details and alternatives. If time allows, more than one prototype should be developed. In the testing phase, the users evaluate the prototype(s) and give feedback. Here, another concentration of the possibility space takes place. This kind of selection closely resembles evolutionary selection in nature, since the selection is applied to the prototype, which in the evolutionary metaphor is the 'phenotype', or actual representation of an idea instead of the conceptual information. Finally, in the iteration phase, the space is expanded again since alternative solutions and improvements have to be figured out. Iteration also means going back to previous process steps and rethinking decisions that have been made there. This may even mean starting from the beginning in order to gather more information. Therefore, the possibility space is widened again.

As shown in Figure 5, there are at least three steps within the design thinking process in which some kind of a selection takes place (once the process is iterated, there might be even more). However, these steps are not explicitly indicated as a selection, and it is assumed that many design thinkers are not fully aware of the significance of specific decisions. Selection is crucial, since the problem in design thinking is usually not the development of a lot of ideas, but rather the selection of the right one.

There are two types of selection errors: selecting a bad idea and not selecting a good one (equivalent to type I and type II errors in statistics). Choosing the wrong idea is not ideal; however, while the idea is tested by users, the problems will quickly become evident, thereby allowing the possibility to go back within the process to iterate the idea.

Not choosing the right idea, however, might have severe consequences. If the potential of an idea was not realized in the first run, the idea might get lost. This indicates the demand for the good communication of ideas, since some ideas might just not be understood by everybody, and also the need for some time to recapitulate the concepts. Also, the ability to store the ideas that were not chosen for possible later use is crucial to ensure retention.

In design thinking, the emphasis lies on the voting mechanism. In the evolution metaphor, this mechanism is an 'artificial' selection determined not only by democratic parameters, but also by the subjective and personal tastes of the team members. In nature, however, the selection occurs differently: it is determined by the environment. The "survival of the fittest" [12] means that only those species survive that are best adapted to the environment. In design thinking, this could be compared with the testing phase. The prototype that receives the best feedback by the users is going to survive. In fact, the users, not the design thinkers, select the prototypes. The selection of prototypes is actually better than the selection of ideas since it is difficult to judge raw ideas instead of real products. Therefore, the ideas need to become more tangible (or turned into the actual representation—the phenotype) in order to be judged by the environment, i.e., the users. The testing of prototypes leads not only to a binary survival decision, but also qualitative feedback about why a prototype is not satisfactory is gathered. This feedback can be used in the next idea iteration. Therefore, design thinking can be described as a Lamarckian evolutionary process. The whole concept of selection of the prototype, however, is not consciously thought through in design thinking and could be given more emphasis.

As described earlier, there is a third important aspect in evolution: retention. In the design thinking process, there are several steps in which knowledge is being stored or transferred to other team members. During storytelling (which is part of the Point of View phase), insights and findings from the research are shared among the team members. These insights are then condensed into a framework or a persona, which presents a compressed and codified form of knowledge, making it easier to store and transfer this information and increasing retention. The same applies for prototyping, in which knowledge about a possible solution is stored into the physical form of a model (or video, or role-play, etc.) [29, 30, 41], which can later be recalled by other team members or users.

Teams

One of the core elements of design thinking is the multidisciplinary nature of the team members. This could be compared with different species in biology. Only animals from the same species are able to reproduce, but not with a lot of variation, resulting in monocultures. For the most part, animals from different species cannot reproduce at all, or if they can, their offspring are unfertile (like the mule as the result of the reproduction of a horse and a donkey). If this metaphor is applied to design thinking, it means that experts from different areas are needed in order to avoid monocultures that will not generate enough innovative diversity. However, we also need people that are able to communicate and exchange ideas. If everyone thinks and talks in his or her own expert terminology, the communication might fail.

This is where the T-shaped people come into play [2]. As described in the first section, T-shaped people are experts in one specific field, are very open-minded and have strong communications skills, and also possess some basic knowledge in adjacent fields. Therefore, they can connect with other experts and exchange their knowledge to create new ideas. This means that T-shaped people are able to recombine their knowledge better than other experts. This fact not only adds to the generation of ideas, but also fosters retention since these communication skills allow for a better knowledge transfer. See Figure 6 for an illustration.

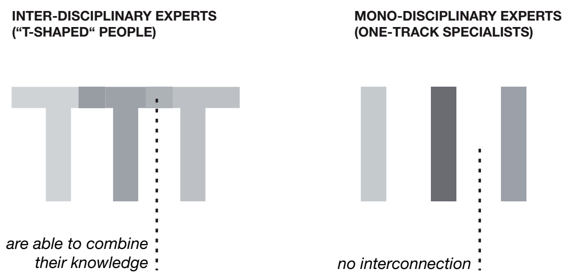

Figure 6: T-Shaped People vs. One-Track Experts

Another concept of the HPI D-School is to "teach teams with teams", which means that not only the student teams, but also the supervising teachers are supposed to be T-shaped experts from different fields. This ensures the inclusion of even more different perspectives that can add to the possibility of recombination and mutation, as well as improve the variation of the outcome.

Environment and Artefacts

As described in the first section, several interesting and special aspects about the D-School's work environment and equipment contribute to design thinking, such as furniture on wheels, sofas, different model-making materials, a library, Post-it notes, and the Time Timer. While a direct relation to creative mechanisms is not evident for some of these, we offer suggestions on the functioning principles of the following items.

The library offers a wide range of inspirational books about design-thinking-related topics as well as other relevant societal topics. These can be utilized as external influences. In natural evolution, some influences activate mutation, such as radiation or toxics. Books are a means to activate mutation, since they provide external inspirations.

Post-it notes, which are also known as sticky notes, are very flexible tools and are widely applied in design thinking. They are used to verbalize or visualize ideas or insights, which helps to communicate insights or ideas and, therefore, fosters retention. Sticky notes also support the recombination of ideas, since they allow for the easy combining of separate notes and the building of clusters. Finally, they also help to select ideas, because they can be arranged and grouped according to specific requirements and priorities. Hence, Post-it notes are a very powerful tool to enhance the creative process on all three levels of evolutionary creativity: generation, selection, and retention of ideas.

The value of the Time Timer is somewhat ambiguous. In natural evolution, time is a very important factor. New species emerge over millions of years. Of course, the whole comparison of evolution and creativity is only a metaphor, and the two are characterized by totally different conditions and prerequisites. However, ideas also need time to grow. Everyone working in creative areas knows that ideas sometimes do not come in brainstorming sessions, but rather during a lunch break after the completion of the brainstorming session, or even on vacation when the entire project is already completed. Also, research shows that a specific state of relaxation can support the creative "flow" [10, 11]. Therefore, reconsidering time management in design thinking, in particular scheduling systematic thinking breaks, is necessary. On the other hand, the Time Timer may also have the capability to activate the above-mentioned 'flow'—a strict sequence of focused cycles, followed by a specific amount of relaxation time, might be the perfect time frame to get into the creative flow. However, better understanding of the impact of time management in design thinking in order to be able to systematically apply the Time Timer more purposefully is still needed.

The purpose of the moveable furniture seems to be mainly practical. Since the demands for the work space change from day to day (depending on the presence of visitors, the working schedule, or occasional presentations), the furniture needs to be carried away from time to time in order to clear the space. Nevertheless, the sofas allow a space for the occasional break from work in order to find some time to relax. This is very helpful concerning the creative flow, as described above. Interestingly, at the School of Design Thinking in Stanford/USA—a partner institution of the D-School in Potsdam/Germany—designated thinking and relaxation spaces have been implemented, which have given the design thinker even more space to withdraw from the busy D-School atmosphere, if needed. Allowing more time for breaks is a very promising concept and warrants further development.

The design thinking workspace contains moveable whiteboards where pictures, drawings, and Post-it notes can be attached. These whiteboards serve as a knowledge repository where ideas and findings are stored in a visual or verbal form and can later be accessed by other team members. That way, the retention of ideas and concepts (genotypes) is ensured. Moreover, the presence of visualised material in the workspace might activate inspiration and 'cross-pollination' between different teams.

Culture

The specific culture described in the first section is not immanent to design thinking in general, but more to the specific atmosphere at the HPI D-School. However, it is worth to analyse how this culture can support the generation of ideas in the context of evolutionary creativity.

The warm-up exercises at the beginning of each day are perceived very differently among design thinkers. For some, it is the highlight of the day, while others feel uncomfortable by the pressure to act in a strange way. Besides the fact that these games allow participants to get 'creatively warm', these exercises have the additional effect of getting rid of the concern about feeling foolish [26]. This allows participants later in the ideation phase to be unafraid to express 'wild ideas' or to make mistakes. Therefore, in a way, warm-up exercises foster mutation. The same applies to games, toys, and music. They lower the barrier for expressing wild ideas and act as external influences that may also foster mutation.

The 'I like, I wish' session at the end of each day is a kind of ritual that aims for reflecting on the process and suggesting improvements, which may help to iterate the whole design-thinking process. This is a kind of metaevolution (the evolution of the process).

Finally, specific mindsets in design thinking deserve a closer look. For example, the slogan "Fail early and often" aims at accelerating the whole cycle of the design thinking process. The sooner an idea is prototyped and tested, the sooner the (eventually negative) feedback can be considered and turned into an iteration of the concept. To continue the evolution metaphor, the selection is being conducted at an earlier time in order to identify those concepts that will not survive. Interestingly, in school and at the job, people are often taught not to make mistakes. The problem with this mindset, however, is that it reduces the willingness to take risks. Those who are afraid to take risks are less likely to come up with something new and innovative.

"Think user-centric", on the other hand, is one of the core principles of design thinking. The goal is not designing for oneself, but rather solving the problems of other people. The constant attempt to put oneself into the position of somebody else generates new findings and allows for the recombination of ideas. Also, the feedback from the users is valuable information and is used as a basis for the selection of concepts.

Ideation Rules and Techniques

In this section, some general brainstorming rules and techniques that are not limited to design thinking alone are presented. The brainstorming rules are derived from Kelley and Littman [27], while negative (also called reversed) brainstorming [15, 24] and the dark horse concept [8, 9] are specific creativity techniques. In Table 2, the impact of these different rules and techniques on evolutionary recombination, mutation, selection, and inheritance are compared.

Ideation Rules and Techniques	Recombi-nation	Mutation	Selection	Retention
Be visual	+		+	+
Defer judgment		+	–	
Build on ideas of others	+	+		+
Focus on topic			+	
One conversation at a time			+	+
Encourage wild ideas		+		
Go for quantity	+	+	–	–
Negative brainstorming		+	–	
Dark horse		+	+	

Table 2: Overview of ideation rules and techniques and their impact on evolutionary creativity

The rule “be visual” addresses the communication of ideas and findings. Verbal descriptions should be supported by sketches or pictures. This rule influences recombination, selection, and also inheritance in a positive way. Ideas and concepts that are communicated in a better way can also be combined more easily and quickly, sorted and selected better, and transferred to other team members.

The rule “defer judgment” supports mutation, since it encourages taking risks and making mistakes, which can result in exceptional and innovative ideas. On the other hand, this rule might complicate the selection process because selection requires judgment. It might be difficult to distinguish between the ideation process (in which judgement is forbidden) and the selection step (where judgment is inevitable), and then to change your position accordingly.

“Build on the ideas of others” supports the recombination, mutation, and retention of ideas. The intention of this rule is to mix different ideas, to take one idea and modify it, and to pass ideas on to other team members for reinterpretation and modification.

To “focus on topic” pertains mainly to the selection of ideas. This rule prevents the group from losing scope. To keep the focus means to select a specific direction to follow and to neglect others.

The same applies to “one conversation at a time”. Additionally, this rule supports the inheritance of ideas because it ensures that everybody in the group gets a chance to express their ideas and that no ideas are lost.

“Encourage wild ideas” supports mutation because it encourages the generation of stupid, crazy, unrealistic, and even dangerous ideas. However, if ‘sane’ or ‘appropriate’ ideas are the only ideas that are developed, these will most likely be predictable and ordinary. The wild ideas especially can offer hooks for something new. Those mutated ideas might not be applicable immediately, but they might have the potential to turn into something innovative.

“Go for quantity” enhances the mutation and recombination of ideas. The more ideas that are developed, the more they can be recombined and modified. As in nature, a substantial amount of source material is needed for mutation and recombination. This rule encourages the production of quantity instead of quality. At the same time, this rule also influences selection and inheritance in a negative way. An information overload makes it difficult to distinguish between important and unimportant information. The more ideas that are developed, the more difficult it becomes to select the right one, which also complicates transferring the good ideas to other team members.

“Negative brainstorming” (sometimes called “reverse brainstorming”) has a similar impact as the “defer judgment” rule, since it supports mutation and encourages taking risks and making mistakes [15, 24]. “Negative brainstorming” also complicates the selection process because the resulting (bad) ideas have to be turned into a constructive solution before they can be selected.

The “dark horse” is a technique that can be compared with the above-mentioned “encourage wild ideas” rule, as its main purpose is to foster mutation [8, 9]. However, the “dark horse” is developed farther than just a “wild idea”. It is already a more detailed prototype of the wild idea: the phenotype. Therefore, it can be used for testing the concept, which supports selection as well.

It is remarkable that the “dark horse” and “negative brainstorming” are the only variations from the usual standard brainstorming techniques used in design thinking. Other creative techniques, such as brainwriting, TRIZ [1], or Osborn’s Checklist [32], have not been considered at the HPI D-School so far. Here, we see the potential to improve the ideation process in design thinking.

Most of the above-mentioned brainstorming rules focus on the creation of ideas, while there are no rules explicitly for the idea selection process. Team members often vote for their own ideas or for those they find most intriguing. However, these are not necessarily the good ideas. Voting is usually conducted spontaneously within 30 minutes after the brainstorming session. There are no rules or guidelines such as “vote for those ideas that are most useful for the user”, or “vote for those ideas that can be implemented in the given time". Some of the brainstorming rules even influence the selection process negatively. "Go for quantity" and "defer judgment" are very important for generating ideas, but they make the selection process even more difficult. Still, those rules have their purpose for generating ideas; however, specific selection rules within the design thinking process are needed.

CONCLUSION

Creativity is more than just idea generation. This article refers to an evolutionary theory of creativity, which is determined by three main aspects: generating ideas (through mutation and recombination), selection of ideas, and retention of ideas. We compare the concept of design thinking—including the process, the team structure, the work environment, the specific culture, and brainstorming techniques—with these three aspects of evolutionary creativity. Design thinking involves many different principles, rituals, and artefacts that are somehow adapted from professional designers and design consultancies, most notably from IDEO. However, most of the people who conducted design thinking in the observed case (the HPI School of Design Thinking) were not fully aware of the working mechanisms of these principles. The goal of this work is to analyse how these design thinking principles function in terms of supporting the creative process, and how the process can be improved.

The findings show that the three aspects of evolutionary creativity can indeed explain the effectiveness of most of the design thinking principles: the design thinking process is determined by alternating phases of generation and selection, the environment and equipment are designed to preserve knowledge and to foster retention, the teams are able to recombine their respective expertise, and the overall culture encourages mutation of ideas and reduces the fear of making mistakes. The rules and techniques for the ideation itself are quite elaborate and support the creative process from different angles, some by stimulating mutation and recombination, others by providing a basis for retention or later selection of ideas. Interestingly, the Lamarckian evolutionary model, which has been proven false in biology, seems to fit better to the evolutionary concept of creativity in design thinking, because qualitative feedback from the prototype (phenotype) is incorporated into the next ideas (genotypes).

We see the main contribution of this article in providing a detailed explanation of the creative mechanisms of the specific design thinking method. Especially in educational contexts, students tend to apply given methods or execute specific process steps, without really understanding why this is important or what the impact of their actions might be. Since for most of the team members theses processes are new, it is crucial for them to understand the reason behind specific rules, rituals, and methods. A thorough understanding of the working mechanisms would give them the chance to avoid mistakes, to execute the process better, and to systematically trigger creative leaps. The work presented in this article provides this understanding and might help design thinkers (mainly students but also practitioners) to enhance their creative output.

Outlook

In our case study we also identified potential for improvement. In particular, the time management, the ideation techniques, and the active idea selection (voting) need some revision and warrant further research.

Concerning the generation of ideas, we suggest implementing different classical creativity techniques (e.g., TRIZ, Osborn's checklist) into the ideation step of design thinking, and then evaluating their impact on generation, selection, and retention of ideas. The effectiveness of such techniques, compared with the brainstorming as it is usually executed in design thinking so far, could be evaluated in an experiment. Further, the impact of time management, and especially the effectiveness of breaks and relaxation on the generation of ideas needs investigation.

Regarding the selection process, we identified a lack of a controlled voting mechanism in the ideation phase. The goal for future work is to create such a set of voting rules—similar to the existing brainstorming rules—that control the selection process and provide structures to better judge ideas.

Moreover, the whole concept of retention seems to be not very well understood. Further research is needed to analyse and explain the specific knowledge transfer mechanisms that are involved in the design thinking process, and how these support the generation, selection, and retention of ideas.

Finally, these findings could help to design collaborative IT support for the design thinking process by highlighting the challenges of generation, selection, and retention of ideas.

Limitations

This article is based mainly on observations within one institution—the HPI D-School in Potsdam, Germany—which limits the representativeness of the work somehow. However, the presented cases are still significant for design thinking in general, since both HPI D-Schools (in Stanford/USA and later in Potsdam/Germany) were among the first educational institutions for design thinking, and the curricula were developed in coordination with IDEO, who introduced the concept of design thinking. Therefore, the HPI D-Schools can be considered pioneers in design thinking. Still, further research, perhaps in a corporate context of design thinking or within other educational institutions, is needed.

Nevertheless, the work represented in this article contributes to a better understanding of the working mechanisms of design thinking, which might help practitioners, students, and researchers to cope with the requirements of working in the field of design thinking.

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