Theoretical Foundations of Design Thinking

Part I: John E. Arnold's Creative Thinking Theories

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Abstract Design thinking is acknowledged as a thriving innovation practice plus something more, something in the line of a deep understanding of innovation processes. At the same time, quite how and why design thinking works—in scientific terms—appeared an open question at first. Over recent years, empirical research has achieved great progress in illuminating the principles that make design thinking successful. Lately, the community began to explore an additional approach. Rather than setting up novel studies, investigations into the history of design thinking hold the promise of adding systematically to our comprehension of basic principles. This chapter makes a start in revisiting design thinking history with the aim of explicating scientific understandings that inform design thinking practices today. It offers a summary of creative thinking theories that were brought to Stanford Engineering in the 1950s by John E. Arnold.

Design thinking is an approach to creative problem solving that is widely recognized as a valuable route to human-centred innovation (Plattner et al. 2009; d.school 2010a; Kelley and Kelley 2013). It has been called a methodology (Grots and Pratschke 2009; Meinel and Leifer 2011; d.school 2015), a culture (d.school Paris 2016; Weinberg 2016) and a philosophy (Katz 2016). The general agreement seems to be that design thinking is a very successful and thrilling practice over and above something more, something in the line of a deep understanding of innovation processes. However, this deeper understanding appears rather hard to explicate. When Hasso Plattner advanced the first two university-based design

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thinking education institutes worldwide—the d.school that started to operate in 2005 at Stanford University and the D-School that was founded in 2007 by the Hasso Plattner Institute at the University of Potsdam—he also started a research program "to understand why and how the Design Thinking method works on a scientific basis" (Plattner 2011, p. v). Ever since, numerous empirical research projects have set out to uncover the regularities, principles, potentials and boundaries of design thinking based innovation work (Plattner et al. 2011, 2012a, b, 2014, 2015, 2016). Reflecting on these activities, Leifer and Meinel (2015) assert that through "cumulative work of a global design thinking research community [. . .] [we] have started to understand the underlying principles" (p. 2).

While never part of an official research project, inter-communal exchange (cf. acknowledgements) spurred joint interests in the history of design thinking—a history that holds the promise of opening an additional and quite valuable door to understanding why and how design thinking works. In particular, it is our hope that historical studies can help the community explicate rather comprehensively the "surplus understanding" that people attribute to design thinking in addition to its being a productive and exciting practice.

At Stanford's Mechanical Engineering department, prior to the teaching of design thinking, at least three earlier concepts informed innovation curricula (von Thienen et al. 2016a). These were *creative thinking*, *visual thinking* and *ambidextrous thinking*. Notably, all of them refer to "thinking". Such a terminological tradition highlights a key concern that design thinkers have embraced up to the present. While design thinking education endows students with methodologies for creative work, a primary goal is still to elicit mindset changes that aid creativity (e.g., Kelley and Kelley 2013; Roth 2015a).

The first historical concept, *creative thinking*, figured centrally in *Creative Engineering* seminars launched by John E. Arnold at Stanford University from the 1950s onwards. Ever since, a strong continuity of methodology, culture and philosophy can be observed up to present-day design thinking classes (Carleton and Leifer 2009; Roth 2015a, b; von Thienen et al. 2016a). To some extent, this continuity is personified by people such as Bernard Roth, Academic Director of Stanford's d.school, and Larry Leifer, Director of the Hasso Plattner *Design Thinking Research Program* at Stanford, who have personally accompanied all theorizing and educational experimentation ever since John Arnold's seminars.

This chapter seeks to make a start in revisiting design thinking history with the aim of explicating theoretical understandings that inform present-day practices. In particular, we attempt to condense Arnold's theories on creative thinking in a few basic claims, relating his terminology to present-day design thinking vocabulary where this seems appropriate. Such an endeavour obviously entails constructive work, as much as we would like to present a purely descriptive review of history. To be as true as possible to Arnold's personal intentions, we complement all interpretations with original quotes. We also wish to encourage every reader to access Arnold's (1959/2016) primary writings, which are very readable in and of themselves.

Furthermore, it must be acknowledged that the approach adopted here appears locally constrained. Our analysis focuses on Stanford University, while design thinking is clearly a world-wide development. At the same time, this research addresses a highly influential institute and gives ample opportunity to recognize contributions from around the globe as they impact Stanford practices and theorizing.

In this chapter, we present a *Part I* study of Stanford's design thinking history, addressing the first historic concept that informed innovation curricula in ways that clearly relate to present-day practices: *creative thinking*. As Part II of the series, we expect to provide an introduction to Robert McKim's need-based design theory, followed by studies of other key innovation concepts: *visual thinking* (Part III) and *ambidextrous thinking* (Part IV). A more traditional narrative of history might then be the final outcome (Part V) in this collaborative research field.

Teachings on *creative thinking* can be clearly traced to one person at Stanford, namely John E. Arnold, because his successors quickly moved on to subsequent concepts. This chapter seeks to explicate Arnold's understanding of *creative thinking* and his pedagogical approach, paying special attention to elements that likely influence present-day design thinking practices. Arnold's last known relevant work, *Creative Engineering* (1959/2016), was compiled at Stanford and can be assumed to provide the latest development of his theorizing; it will serve as nearly the exclusive source of reference. Notably, Arnold's works cover many subjects beyond *creative thinking*. A more comprehensive discussion of his ideas and legacy is provided by Clancey (2016). This chapter also skips a treatment of Arnold's innovative teaching practices at the Massachusetts Institute of Technology (MIT), for which Arnold (1953/2016) provides detailed materials.

We will start with a short introduction to John E. Arnold (# 1) and then summarize his theories on the creative mindset (#2), thinking modes (# 3), problem types (# 4) and creativity blocks (# 5), his definition of creativity (# 6), theory of the creative process (# 7), classification of creativity approaches (# 8), education theory (# 9) and usage of the term "design thinking" (# 10). We will also review some advancements of Arnold's framework and discuss a striking difference between his teaching approach and present-day design thinking education (# 11).

1 John E. Arnold: Collaborator, Experimenter and Visionary

John Edward Arnold, born in Minnesota on 14 March 1914, received his B.A. degree in psychology at the University of Minnesota in 1934 and his S. M. degree in mechanical engineering from the MIT in 1940. In 1942 he joined the MIT staff as an instructor, became an Assistant Professor in 1945 and Associate Professor in 1949. He offered the courses "Creative Engineering" and "Product Design" at the MIT and later at Stanford University, where he was appointed Professor of Mechanical Engineering and Professor of Business Administration in 1957. He was founding

Director of the Design Division at the Mechanical Engineering Department. At age 50 he died of a heart attack while travelling in Italy on sabbatical.

In his theorizing, Arnold integrated a cornucopia of influences. First, he personally collaborated with leading creativity experts, famous up to the present. For instance, the psychologists Joy Paul Guilford and Abraham Maslow, the philosopher Robert Hartman and the architect Buckminster Fuller: all came as guest lecturers to his Stanford class on *Creative Engineering*. The first three even contributed essays specifically written for Arnold's seminar, summarizing their research on creative thinking and implications for practice. Arnold was also a well-versed reader and included in his framework insights from Heraclitus, Aristotle and Schiller to recent figures of his time such as Wallas, Osborn, Wertheimer, and Bruner. He regularly held seminars for the industry and was very familiar with innovation processes used there, including General Electrics and General Motors. Case studies of outstanding innovators, diverse empirical creativity studies and Arnold's personal, effervescent experiences as an educator, who liked to experiment with different teaching approaches, all informed his theories.

Creative Engineering (1959/2016) describes in detail two major pillars of Arnold's creative thinking framework. One is an elaborate compilation of methods that can be serviceable along the creative process. The second is a set of theories about creative thinking. In the latter, a description of the creative mindset figures prominently. Arnold asks: What distinguishes a person who achieves creative, innovative solutions from someone who achieves less in these areas? As one might expect, methods shall help students expand their creative problem solving competencies. But, maybe more importantly, practicing methods shall impact the mindset in favour of creativity. This chapter is concerned with Arnold's theories on creative thinking only and does not review his compilation of methods, which are however discussed by Clancey (2016).

To facilitate future research and help the community build on Arnold's works, we will highlight a number of central theoretical assumptions (A), definitions (D) and include some observations from a meta-perspective, as informed by design thinking research (M).

2 A Theory of the Creative Mindset

Arnold's theory of the creative mindset presented in *Creative Engineering* (henceforth CE) builds to a large extent on Joy Paul Guilford's factor-analytical studies of creativity. Arnold also includes lines of thought from a number of other researchers, among them Abraham Maslow, who compared highly creative and rather rigid people, Carl Rogers, who described creativity as an attribute of healthy humans that would allow people to realize their personal potential, and Dana Farnsworth, who elaborated on emotional prerequisites of creativity. Arnold also weaves in personal observations and analyses.

> The four Guilford factors of (1) problem sensitivity, (2) fluency, (3) flexibility, and (4) originality appear repeatedly in almost all of the literature on creative thinking, imagination, and innovation, although not always under the same names. You would not, however, until Guilford isolated them in his factor studies, know that they have been recognized as basic mental attributes, and ones essential to the creative, imaginative thinker. This is true whether he be a poet, an artist, an engineer, or a physicist. They are part of the inherited potential of each individual, and combined with certain emotional attributes make up the personality of the innovator.
>
> (CE, p. 96)

This review will start with Arnold's interpretation of the factors that he adopts from Guilford. Arnold adds three emotion-centred variables to describe creative mindsets, which will be introduced afterwards.

A1) The creative mindset is characterized by problem sensitivity, fluency, flexibility, originality, daringness, drive and confidence.

D1) Problem sensitivity refers to the inclination of a person to notice and tackle problems next to abilities of framing, defining and communicating problems in ways that aid creative solutions. Starting off with Guilford's definition, Arnold agrees that problem sensitivity includes the ability of a person to notice problems.

> Problem sensitivity, as originally conceived and defined by Guilford was that ability that made men sensitive to their surroundings. Rogers and Mooney speak of this as "openness to experience," possibly a more inclusive term. It is being aware that a problem exists. Sometimes it is no more than a feeling, a hunch, that can't be clearly defined until a great deal more investigation and study is carried out.
>
> (CE, p. 80)

In addition, the problem sensitive person is described by Arnold as someone with a "deep spirit of inquiry, of questioning" (CE, p. 63) who seeks to "improve the things he sees" (p. 63). Thus, faced with questionable life conditions, the problem sensitive person does not only notice a problem, but also develops the interest and intention to follow up on the "hunch"; this person is ready to invest time and effort.

A third aspect that Arnold brings into play is the ability of describing problems in clear and fruitful terms.

> I have found from my own work, however, that problem sensitivity involves more than an awareness of problems, for it also seems to be associated with problem statement [. . .]. Problem statements may limit or free the imagination of the solver. They may precondition his thinking along such narrow and rigid lines that very desirable solutions are precluded. At the other extreme, I suppose they can be so nebulous and ill-defined that no one knows what is wanted or where to start.
>
> (CE, p. 80)

Here, Arnold explicates a central theoretical belief that informs design thinking up to the present. It calls for an optimal balance between focus and degrees of freedom.

M1) Problem framing opens, closes, and structures solution spaces.

In design thinking, Arnold's ideas about problem framing appear to be mirrored in the motto: "Craft Clarity[:] Produce a coherent vision out of messy problems. Frame it in a way to inspire others and to fuel ideation" (d.school 2010b, p. 0). Like

the d.school Bootcamp Bootleg, Arnold calls for intriguing problem statements, which provide directions for successive creative activity.

D2) Fluency refers to the number of ideas that a person produces per unit time. "The creative person is more fluent in his ideation than the less creative; he has more ideas per unit time" (CE, p. 84). Arnold's discussion of fluency is to a large extent informed by empirical relationships he observes. Next to the influence of judgmental thinking that will be discussed below (# 3), problem framing is accorded great attention again.

A2) General or loosely constrained problem statements increase fluency; narrow or highly constrained problem statements reduce fluency.

A3) Disregarding practical limitations when generating ideas increases fluency.

> I recently gave my students a short case problem aimed at getting people across the Harvard Bridge [. . .]. Those who tried to think of ways and means of transporting "feeble old ladies" safely across the bridge under the worst possible conditions had a very difficult time of thinking up any suitable solutions. On the other hand, those who realized that the above limitations might have to be applied to the final solution, but who temporarily laid them aside and considered every possible means of getting something from one place to another came up with over 75 different ideas in a little under twenty minutes.
>
> (CE, p. 85)

D3) Flexibility refers to the number of meta-options a person considers per unit time. Meta-options include categories, points of view, approaches, solutions, and so on. Arnold names several domains where flexibility is important, including (1) *Object Use:*

> [Guilford asks] people to list as many uses they could possibly think of for very common, every-day items such as a red brick. People could show a great deal of fluency in their thinking by listing a long column of uses, but they all fell into one category such as construction or ornamentation, they showed little flexibility. Actually there are some fourteen categories under which you might list the uses of bricks and the flexible thinker gives some thought to most of them. Bricks have mass as well as spacial dimensions. They make good doorstops or bookends [. . .]. Bricks have color and they might be ground up to form pigment for paint [. . .].
>
> (CE, p. 85)

Another domain concerns (2) *Work and Solution Approaches:* "Flexibility [. . .] reflects itself in the wide variety of approaches that the creative person chooses to investigate" (CE, p. 85). (3) An *Action-Reflection-Role-Repertoire:*

> Flexibility [. . .] is also the ability [. . .] that allows you to be both an observer and a participator at the same time or in alternation. It is most desirable to have this duality of personality be constant in time if the observer half is not acting as a judge [. . .]. Perhaps the alternating roles would be the safest at first. This would allow you to step back every so often and review what you have done to date and to reconnoiter and determine the best path to continue along.
>
> (CE, p. 86)

With these thoughts, Arnold anticipates the concept of a *reflective practitioner* that was later elaborated by Donald Schön (1983) and thoroughly embraced in the design thinking community (Lindberg 2013). As yet another domain where the

creative thinker needs to demonstrate flexibility Arnold mentions (4) *Work Pace:* "Flexibility [. . .] is the ability to change pace used so successfully by athletes" (CE, p. 86). (5) *Perspective-Taking:* Flexibility allows the creative thinker to take on "a number of different vantage points" (p. 86). (6) *Perceptual Inclinations:* Arnold requires great flexibility of the expert innovator who should have "his senses so trained that their thresholds of perception can be varied at will. His powers of free and controlled association must be developed to an extremely high level so that he can search out and find extremely remote relationships" (p. 129).

D4) Flexibility is the opposite of rigidity. A rigid person tends to converge always on the same options. More generally speaking, "the non-creative person's past experience provides him with a comfortable little rut in which to operate and he has great difficulty getting out of that groove" (p. 85). Similarly, the rigid environment favours continuity with the past. In a rigid environment "people resist change and innovation" (p. 87). They prefer "the old, familiar, and seemingly adequate ideas that they have held for some time" (p. 87).

D5) Originality refers to the unusualness of ideas. "It must be obvious that the highly creative person makes more novel and original combinations than the less creative. He consistently brings together 'seemingly disparate' or 'habitually incompatible' ideas or objects [. . .] to form tenable and useful new combinations" (p. 86). Here, Arnold brings into play the concept of "habitually incompatible ideas" from Arthur Koestler (1949), meaning ideas that most people normally would not associate with each other, though it is possible to do so.

Next to the Guilford-factors, Arnold also discusses attributes that Carl Rogers and Abraham Maslow assign to creative thinkers as opposed to rigid thinkers. These include *openness to experience*, *being playful*, *humorous*, *not afraid of fantasy* and having an *internal locus of judgement*, i. e. non-conformity, not depending universally on what other people hold to be right or wrong. Yet, Roger's and Maslow's works inform Arnold's interpretation of other mindset variables rather than entering the framework as disjunctive elements.

Besides the re-interpreted Guilford factors, Arnold highlights three variables that focus specifically on motivational or emotional processes. All of them are related to an issue that he discusses regularly in his theorizing: Being an innovator is challenging because innovation projects often encounter obstacles or even straightforward resistance from people who defend the status quo.

M2) A creative mindset requires emotional and motivational attributes that help to overcome innovation hardships.

Innovators need strong impulses to engage in their work despite all the hardships this often entails. Specifically, Arnold highlights boldness in the face of risk (daringness), enthusiasm for problem-solving (drive), next to believing in oneself and one's vision (confidence).

D6) Daringness refers to the willingness of a person to challenge the status quo and risk the untried. Notably, this often includes social risks, as other people may prefer the status quo or may be sceptical about a novel solution they have little experience with.

> The creative person has to be daring. He [. . .] must constantly take calculated risks in his attempt to find better solutions to the problems that face mankind. He cannot stick to the safe, the tried and true, the prosaic approaches, and he must pioneer in new areas in a very daring fashion. Creating, unfortunately, also involves destroying. The man who is seeking a new, better solution to an old problem [. . .] wants to destroy a present, possibly adequate solution. As John Steinbeck has pointed out, many people resist change and innovation not so much because they fear the new approach, but because to accept the new they must first give up the old, familiar, and seemingly adequate ideas that they have held for some time. The creative individual, then, must be a leader, he must be daring.
>
> (CE, p. 87)

D7) Drive refers to the emotional energy and enthusiasm with which a person pursues her creative project, specifically when facing hardships. Arnold observes that truly creative thinkers love to solve problems. "Many studies have been and are being made on motivation, initiative, and so forth, and the new insights give us a more complete picture of their phenomena. For the most part it seems however, that the highly creative person just loves to solve problems. The great inventor invents because that is what he likes to do best; the great painter creates great works of art because that is what he likes to do" (CE, p. 87). "Drive [. . .] connotes a very definite enthusiasm for work; again this love of problem solving" (p. 87). However, as creative work often confronts obstacles, drive also refers to emotional energy that is maintained in times of hardship.

> Many people have indicated that they feel that this [drive] is the prime requisite of all creative workers. Edison, for example, has said that invention is two percent inspiration and ninety-eight percent perspiration. I am not quite sure that he had the percentages accurately distributed, but I do know that there is a great deal of work associated with the polishing and re-polishing of an idea before it becomes an acceptable, tangible result.
>
> (CE, p. 88)

D8) Drive is observable as perseverance, specifically when facing hardships or immediate but moderately helpful solutions. A person who lacks drive likely fails to carry the "problem through to completion and test" (CE, p. 92)—and even more so when faced with obstacles. Or the person will accept "a workable solution [. . .] [instead of] searching for a better one (grabbing the first idea that comes along)" (p. 92).

A4) Drive is a major predictor for creative achievement.

> A number of patent attorneys (176), research directors (78), and inventors (710), were asked to list the mental characteristics that were necessary and vital to the successful innovator. The patent attorneys and research directors listed originality and imagination, analytical ability and perseverance at the top of the list, and in that order. The inventors, on the other hand, changed the order slightly, and I am inclined to agree with them. They listed perseverance as number one by a wide margin, and then originality and imagination and finally analytical ability. Without the drive to carry a project through to completion, in spite of all obstacles, the idea has little or no value.
>
> (CE, p. 104)

D9) Creative confidence refers to positive beliefs held by a person about her own innovation capacities and the value of her creative project. "There are so many ways in which a good idea can be destroyed or made quite impotent that confidence in one's cause [. . .] is a prime requisite to innovation" (CE, p. 88).

A5) Confidence is an important moderator variable that affects whether or not people maintain drive in the face of obstacles; with high levels of creative confidence people retain more drive in times of hardship.

Two case studies illustrate the role that Arnold attributes to confidence in the course of creative activity. Discussing Land's invention of Polaroid pictures and Gillette's invention of disposable razors, he summarizes: "In both cases, reason and analysis (the experts) said that it couldn't be done. [. . .] In both cases, a certain amount of confidence, or intuition or faith provided the emotional energy or drive to carry the project through and make the big dream come true" (p. 104).

While not part of his theory of the creative personality, Arnold also discusses how creativity and happiness relate to each other. He holds that "to be happy one must be creative" (p. 64).

A6) Happiness requires creativity.

D10) Happiness depends on personal achievements in the sense of making contributions to society and realizing personal potential. "The definition that I like best is that happiness is the first derivative of your achievement curve. When you are progressing, making positive contributions and using your talents to the full, the slope of the achievement curve is positive and you are happy. The opposite situation results in a negative slope and unhappiness" (p. 63f.). "One must make positive contributions to society, must maintain an achievement curve with an overall positive slope if one is to be truly happy. This is one more good reason for why we should try to be creative" (p. 64).

In the design thinking community, this theme is advanced in *The Achievement Habit* (Roth 2015a), where readers are encouraged to express and develop their creativity as part of self-actualization.

3 A Theory of Thinking Modes

Once more building on—and putting his own spin on—Guilford's analyses, Arnold lays out his understanding of different thinking modes. "Dr. J. P. Guilford [. . .] first hypothesized the three modes of thinking as analytical thinking, judicial thinking, and creative thinking" (CE, p. 80, cf. also Guilford 1950). According to Arnold . . .

A7) There are three basic modes of thinking: Analytical, judicial, and synthetic.

D11) Analytical thinking detects the features and structure of an entity. "Analyzing is the taking things apart in the search for truth and recognizable relationships" (CE, p. 129). As sample fields of study that primarily require analytical thinking, Arnold names pure logic, mathematics, and system analysis.

D12) Judicial thinking compares two or more entities and often ascribes value. However, "effective judgments cannot be made completely independent of analysis. This must almost be obvious. When one is comparing, making value judgments, rating, classifying, deciding, and so forth, it is essential that keen analysis be made of each of the components involved" (p. 66). As sample fields of application, Arnold

names jurisdiction and quality control, as "both of these areas of activity depend primarily on making good judgments, making right decisions" (p. 73). The terms ***judicial thinking*** and ***evaluation*** are used synonymously.

D13) Synthetic thinking combines two or more entities into something new. It is "the bringing together of two objects or concepts for the purpose of making a new combination or whole" (p. 66). As sample fields that require synthetic thinking, Arnold names machine or product design, art, music and philosophy.

D14) Creative thinking combines analytical, judicial, and synthetic thinking in regulated ways. Thus, creative thinking is not a thinking mode in itself but a combination of thinking modes. Creative work needs a careful "balance between analysis, synthesis, and evaluation" (p. 129). This includes up-regulating and down-regulating the thinking modes at will. Especially in the idea generation phase it is important to dispense judicial thinking. One reason is that "fluency is definitely facilitated or inhibited by the absence or presence of simultaneous evaluation. Evaluation must be restrained temporarily while one is thinking up ideas or hypotheses" (p. 84). However, after the solution space has been saturated with a great number of diverse ideas, judicial thinking is essential. "The solutions obtained can form a complete spectrum from bad to good. [. . .] [T]he choice of the best possible solution depends upon careful evaluation of the many presented for consideration" (p. 129).

4 A Theory of Problem Types

Closely related to the theory of thinking modes, Arnold presents his theory of problems.

A8) There are three basic types of problems: Analytical, judicial and synthetic.

"Problems can be classified into three quite distinct groups: analytical, judicial, and synthetic" (p. 65). Arnold believes "that the three types of problems [. . .] stem from the three basic modes of thinking, analysis, evaluation, and synthesis" (p. 65). However, to distinguish between different problem types, other criteria are suggested.

A9) Problem types can be distinguished based on (a) the number of concepts that need to be considered in problem and solution statements next to (b) the number of correct answers.

D15) Analytical problems (a) are characterized by precise problem and solution statements that use only a small number of concepts and (b) they have only one correct answer.

> Analytical problems are stated quite precisely and involve, both in statement and solution, a relatively few basic concepts which lead to one, and only one, right answer. [. . .] What is the sum of 2 plus 2? Who won the Battle of Hastings in 1066? [. . .] In all cases, correct processes of logic or experiment will yield the one right answer; all other answers are wrong.
>
> (CE, p. 65)

D16) Judicial problems (a) are characterized by complex problem and solution statements that require intricately refined concepts and (b) they have more than one correct answer. Paradigmatic examples are drawn from the field of jurisprudence.

> The problems of judgment are somewhat more complex. It takes many more words and concepts to describe them, in fact, to all but the legally trained mind, the verbosity of legalese is extremely confusing. Not only must you describe in great detail the "things" that must be evaluated, but you must also be just as meticulous in stating the bases for judgment, the rules, the laws that must be followed.
> (CE, p. 65)

Many answers can be defended as right, and answers that were considered right once can be turned down later on. "In the law a higher court can reverse a lower court decision, and in the Supreme Court minority reports are frequently submitted" (CE, p. 65). Another example would be beauty contests where "it must be a rare event when there is complete agreement between the judges" (p. 65).

D17) Synthetic problems (a) are characterized by an open spectrum of concepts that can be invoked for problem and solution statements and (b) an infinite variety of possible solutions from bad to good. "The problems that involve synthesizing [. . .] may involve an almost infinite number of concepts and a complete spectrum of possible solutions. The cross products of the various factors that might be combined in any one problem are almost limitless" (p. 65). On behalf of the solutions Arnold holds that there are

> many right answers, many wrong ones and all possible combinations in between. Moreover, this spectrum is never completed. No matter how poor the worst solution existing in the spectrum is, a still worse one can be found; and in the same manner, but perhaps with more effort, a still better solution than the best one existing can be found.
> (CE, p. 65)

With the category of synthetic problems, Arnold anticipates "wicked problems," a concept later coined by Rittel (e.g., 1972; Rittel and Webber 1973) that is much attended in design thinking research (e.g., Buchanan 1992; Lindberg 2013; von Thienen et al. 2014, Ney in preparation). Notably, Arnold's classification is conceptually more economic; he invokes only two criteria to distinguish between different problem types, while Rittel uses ten criteria.

Solving problems with more than one correct answer requires creativity; hence they are also called "creative problems".

M3) Creative problems centre on basic human needs that are either not satisfied at all or badly satisfied at present.

M4) Solving creative problems means to improve ways of meeting basic human needs.

Notably, in Arnold's problem conception solving a creative problem means to satisfy basic human needs. Being sensitive to problems—as part of the creative mindset—is already interpreted as seeking to better satisfy basic human needs. "The highly imaginative person is one who is motivated by a deep spirit of inquiry, of questioning. He is constantly asking himself how he can improve the things he sees.

He is concerned with how the basic needs of man can be better satisfied" (p. 63). The goal of creativity is to "better satisfy some basic need of mankind" (1956, p. 8). Here, addressing basic—instead of variable and superficial—human needs means to dig deep into a problem, seek a broad perspective and understand the general issues that are at stake. Traffic organization is one example that Arnold invokes to illustrate varying problem scopes and the needs they bring into focus. A customer might ask for a small car to ease parking in a crowded city. The 'need for a small car' is everything but a general, fundamental need. Arnold follows up with a question: Why does this person need to use a car and find a parking space for it? His answer is that people "must be kept mobile—yet not be overly frustrated" (CE, p. 94). The needs 'to be mobile' and 'to not suffer frustration' are already much more basic. Yet, Arnold digs even deeper and asks: Why do people need to be mobile? Here, the answer is that "man must be able to communicate freely" (p. 94), which arguably brings into focus a yet more basic need than mobility. (The subject of basic needs and how to identify them in the context of design thinking is treated in detail by von Thienen et al. (2012a). Clancey (2016) elaborates on Arnold's philosophy of design where human needs that shall be addressed by design often bear on social or societal challenges.) The idea that creative solutions satisfy human needs is also part of Arnold's creativity definition and discussed further below (# 4).

5 Theory of Creativity Blocks

Creative mindsets, thinking modes and problems are central elements in creative activity. With his theory of creativity blocks, Arnold starts a systematization of factors that hinder creative work.

> It is possible for an individual to have a rather highly developed potential for creative activity and who is potentially able to balance his ability to analyze, synthesize and evaluate, and to have the necessary initiative and drive to complete his novel ideas, yet to find himself in situations where it is almost impossible for him to work efficiently and effectively. These factors that tend to inhibit and prevent productive and creative activity we will call blocks. (CE, p. 88)

D18) Creativity blocks refer to factors that antagonize creative activity. Arnold suggests to "loosely group them under three headings, loosely because the things that affect thinking and action rarely if ever appear in pure culture. The headings I would suggest are *Perceptual Blocks*, *Cultural Blocks*, and the *Emotional Blocks* to creative activity" (CE, p. 88f.). They range from short-term or rather specific blocks, such as not knowing enough about a specific field of inquiry, to general, stable and often personality-related blocks, such as seeking to be a "well-adapted" member of the community who never deviates from common practices.

D19) Perceptual blocks antagonize the understanding of problem and solution spaces by making information unavailable or distorting it. People "fail to get true, adequate, and relevant information about the outside world" (p. 89). Sample blocks are a "failure to use all of the senses in observing" (p. 92), "difficulty in narrowing

the problem too much (paying little or no attention to the environment)" (p. 91), "difficulty in seeing remote relationships (inability to transfer)" (p. 92) or "difficulty arising from not recording 'trivia[']" (p. 92).

D20) Cultural blocks refer to social influences that antagonize the progress or flexibility of creative activity. "Our culture influences our thinking and our activity. [. . .] Certain things are done in our society, other things are very definitely tabooed" (p. 90). A person falls victim to a cultural block when she allows herself to be driven by a "desire to conform to an accepted pattern" (p. 92) and thus limits her own flexibility. A creative process may fail to get started in the first place when the person finds it "not polite to be too inquisitive and not wise to doubt everything" (p. 92). In research and engineering, a sample cultural block can be having "too much faith in statistics" (p. 92).

D21) Emotional blocks are emotions that limit the person's ability to develop and/or exploit her creative potential. "The emotional blocks are by far the largest grouping, and they include all our fears, and most of the defense mechanisms that we build up in order to make our lives seemingly more tolerable" (p. 89). Sample emotional blocks are the "fear of making a mistake or making a fool of yourself" (p. 92), an "over-motivation to succeed quickly" (p. 92), a "lack of drive in carrying [the] problem through to completion and test" (p. 92) or having "difficulty in rejecting a workable solution and searching for a better one (grabbing the first idea that comes along)" (p. 92).

6 Defining Creativity

As for all practical purposes, Arnold holds that . . .

D22) A solution is creative when it is novel and useful. This definition he invokes frequently, with some variation of vocabulary. He concerns himself with "novel and more useful solutions" (p. 83), "new and useful ideas" (p. 106), "useful new combinations" (p. 86) etcetera. However, for academic purposes, he invokes a more refined definition.

> Now it is not just any synthesizing process combined with analysis and evaluation that I would like to call creative activity. There are certain restrictions and qualifications that I should like to make. The creative process is primarily a mental process whereby one combines and recombines past experience, possibly with some distortion, in such a fashion that the new combination, pattern, or configuration better solves some need of mankind. In addition, the end result must be tangible, something you can see, feel, or react to in some way, it must be forwardly oriented in time and it must have synergetic value.
>
> (CE, p. 66)

Here, from the perspective of design thinking research, the strong concern for human needs—which even enter Arnold's definition of creativity—is once again striking.

D23) A creative solution is useful when it (better) satisfies a human need. This concern for human needs runs through all of Arnold's theorizing. For example,

creative work "is concerned with how the basic needs of man can be better satisfied" (CE, p. 63). New solutions are developed to "better solve some need of man" (p. 77) and he takes for granted the goal that "our innovations *better* satisfy some need of man" (p. 67, emphasis in original). Arnold's strong concern for human needs does not only match present-day design thinking values, but is also remarkable from a historical perspective. For instance, in Dubberly's (2004) historically organized compendium of design models, the first approach that talks about satisfying needs dates from 1967.

Another point that Arnold emphasizes repeatedly is that creative work needs to yield a tangible result in the end, "something you can see, feel, or react to in some way" (p. 66). In his definition of creativity, the quick transition from a "mental process" to "tangible end results" already points to the importance of prototyping in design thinking.

D24) The creative process ends not with an idea but with a tangible outcome. Arnold gives two major reasons why tangible outcomes are important. First, a lot of creative mastery may be necessary to translate an abstract idea into a practical and workable solution. "There is 'many a slip 'tween the cup and the lip'; there are many 'bugs' that must be worked out of the best conceived ideas; there is ample opportunity for high level creative activity in the development of a prototype" (p. 67). Second, thinking up ideas is usually a rather benign process. By contrast, trying to implement a new solution often stirs up forces of continuity that try to defend the old status quo. "Many people resist change and innovation [. . .] because to accept the new they must first give up the old, familiar, and seemingly adequate ideas that they have held for some time" (p. 87). "Without the drive to carry a project through to completion, in spite of all obstacles, the idea has little or no value" (p. 104).

D25) Creative solutions are forwardly oriented in time. This criterion shall serve "to distinguish between wholly judicial activity and that which should properly be called creative. A good share of legal activity, for example, is centered around solving problems of the past" (p. 68). A judge might thus face the "past problem" that someone undertook a criminal act, which needs to be addressed by society. For creativity in a strong sense, Arnold holds that people rather need a concern for and a "vision of the future" (p. 68). While Arnold considers the criterion of future-orientation "probably an academic restriction" (p. 67), the idea continues to inform creativity discussions. The aspect of planning ahead and designing solutions that impact the future is coherent with present discussions on the relationship between creativity and anticipation (Corazza 2017).

Finally, Arnold mentions that creative solutions must display "synergetic value" (p. 66). Yet, he admits that this "is a big word for the old concept that invention is characterized as a new combination of old parts whose new value is greater than the sum of the individual parts" (p. 68). Thus, it appears to be mostly a reformulation of the more common criteria that creative solutions are novel and useful.

As an important qualification, Arnold adds that the criteria he provides in his definition of creativity shall serve as ideals that guide and motivate creative activity, while the overall goal will be achieved only occasionally.

A10) Creativity criteria provide ideals to strive for in creative work.

Above all, "the *better* stipulation is a difficult one to meet and it may have to be thought of for a while as an ideal to strive toward but not quite reach, that is, for the most of us. The genii of all times achieve the goal occasionally" (p. 67).

> The person who is just starting to learn to apply the creative process will find it very difficult at first to meet all the qualifications that we have set up for true, high level creative activity. But he should not be discouraged. If, in arriving at his solution, he does meet some of the factors we have listed, his work in some measure may be classified as creative.
> (CE, p. 72)

Thus, Arnold also introduces levels of creativity and creativity metrics.

A11) Creativity criteria help to assess creative achievement: The more criteria a solution fulfils, the higher the level of creative achievement is.

> Probably one of the most difficult things to do [...] would be to try and define the various levels of creativity that we know must exist. If we are very strict and stick to the very rigorous definition first given and insist that all the limiting conditions be met, we would probably have only a few categories that would include only the works of men of demonstrated genius. This would be just the upper end of a spectrum which is undoubtedly continuous. Removing the qualification that the new combination must exhibit synergism would increase quite markedly the number of acts that might be called creative; and then, one by one, removing the other restrictions until we finally reach the point where any new combination, new, that is, to you, might be classified as rather low-level innovation.
> (CE, p. 72)

7 A Theory of the Creative Process

The creative process is fundamental in Arnold's framework. He considers it to be a key element that creativity phenomena in different domains have in common.

> I think that the creative process itself is unique and also is a universal process that applies to all kinds of creative activity, whether you are an artist, or a poet, or a composer, or an engineer, in the military, in the business world, in the professional world, teaching, and so forth. If you are being creative, if you are looking at and solving problems in a creative fashion, you are using a similar process in all cases. The tools you work with, of course, vary from individual to individual, from group of activity to group of activity [...].
> (Arnold 1956, p. 7)

A12) The creative process is to a considerable extent domain-general.

One key element in Arnold's understanding of creative activity is that it is a process of problem solving. Indeed, prior to lecturing on "creative thinking", the concept of "creative problem solving" dominated his teaching (cf. Arnold 1953/2016,1956).

It is the process a person follows, rather than the problem (s)he works on, that determines for Arnold the degree of demonstrated creativity.

> It is possible, perhaps in more cases than not, to successfully solve multisolutional creative type problems in anything but a creative fashion. The machine designer who chooses from the many possible fastening devices to use a spline in attaching a gear to a shaft is tackling

> a creative problem in a routine prosaic manner. On the other hand, a scientist may be faced with a highly analytical problem (by definition), searching for the one right answer from nature, but if he solves it with an open mind, great imagination, daringness, and enthusiasm, he is being highly creative. The process you use is the deciding factor in large measure as to whether or not you are creative. The problems you work on and occasionally even the products that result can be worked on and solved by non-creative techniques. Pure chance, for example, could produce seemingly creative results.
>
> (CE, p. 71f.)

A13) Whether or not a person is acting creatively depends mostly on the process (s)he follows.

As a minimum requirement, Arnold's suggestions may be summed up to the following definition of a creative process:

D26) The creative process is a process of problem solving in which the creative agent seeks a novel solution to better satisfy basic human needs—capitalizing on a creative mindset and balancing all three thinking modes along the way.

Notably, this understanding of creative processes is very remote from concrete process steps or methodologies. In fact, Arnold discusses a great variety of design models and methods that people can adopt. This includes process models from Wallas, Osborn, Gordon or General Electrics and methods such as the area method, attribute listing, brainstorming and morphological analysis (cf. Clancey 2016 for a more comprehensive overview). Arnold also discusses an approach he uses regularly in his own projects. Like present-day process models of the d.school (2010b), the "stages" that Arnold differentiates are primarily considered as mindset modes rather than sequential process steps. "The four key words that I find especially useful for my thinking: Question, Observe, Associate, and Predict. [. . .] I don't actually like to think of them as steps of a process that are followed in a certain definite sequence. To me these four words represent attitudes of the mind" (CE, p. 117).

Arnold advises his students to familiarize themselves with numerous methods and to experiment with them. While to Arnold creative activity is always a process of problem solving, the invoked methods will vary by domain, problem, and person.

> It is probably not necessary to give this warning, but to assure that there are no misunderstandings, remember well that there is no one right answer to creative problems. The search for aids to problem solving is a highly creative task. The approaches suggested in this chapter are not sacred and they should be modified and changed to fit the individual needs of the person using them. They are not the one right answer. It is hoped, in fact, that you will never rely on one or two rigid patterns, but that you experiment just as much with the processes by which you solve problems as you do with the problems themselves.
>
> (CE, p. 96)

Here, Arnold submits his understanding of methodology, which design thinking education continues up to the present. Leading educators stress carefully that design thinking itself is something quite different from, and goes far beyond, the methods that are taught in class. This subject will be explored in more detail below (# 9).

From a theoretical point of view, notably, Arnold uses the term "process" sometimes to reference a domain-general activity of problem solving, and sometimes to

reference very concrete behaviours, which vary from one creative activity to the next.

8 A Classification of Creativity Approaches

One way in which Arnold analyses different forms of creative activity, highlighting differences and similarities of creative processes that he considers important, is by invoking a classification of creativity approaches. Depending on the chosen approach, Arnold expects as the outcome either incremental or disruptive change.

A14) There are two types of creativity approaches, *organized* and *inspired*, and combinations hereof.

D27) Organized creativity approaches follow a step-by-step rational. "The group of organized approaches is so named because they usually exhibit a logical, orderly, step-by-step type of problem solving technique" (CE, p. 73). In this category, Arnold mentions the *Empirical* or *Trial-and-Error Approach* and the *Rational Approach*. "The empirical approach, frequently [also] called the Edisonian approach, consists mainly of an endless number of trial-and-error experiments" (p. 73). An example would be Edison's search for incandescent filaments, where "it has been said that [. . .] he tried over sixteen hundred different materials, even including Limburger cheese" (p. 73). By contrast, with the rational approach "a lot of wasted motion and effort is prevented by a more thoughtful approach to the problem solving situation. [. . .] Careful thought is given to the statement of the problem and the setting up of [. . .] hypotheses to be later tested by experimentation" (p. 75). An example is Migley's invention of "a better refrigerant in 3 days time. Most of this time was spent in contemplating the periodic table and synthesizing, analyzing and evaluating mentally. After he had decided what the new combination should be, he made one and only one experiment, and, fortunately, this experiment verified his hypothesis and Freon was developed" (p. 75).

D28) Inspired creativity approaches build on intuition, fantasy or other loosely controlled psychological processes; they are characterized by relaxed ties to that which is considered possible, advisable or state of the art in the domain of creative work. In this category, Arnold distinguishes between the *Big Dream Approach* and the *Flash-of-Genius* or *Insight-Based Approach*.

> The big dream approach [. . .] is carried out by asking yourself the biggest question you possibly can, by dreaming the biggest dream that you possibly can, by sort of soaring off into space with a grand idea, and then expending every possible effort to answer this big question, to make this big dream come true, to get some tangible tie between your flight into space and solid reality.
>
> (CE, p. 76)

The *Flash-of-Genius* is about "insightful behavior. It ranges from the common experience of trying to remember a forgotten name to Archimedes running naked down the street shouting 'Eureka'" (p. 76). Despite its name, which seems to

allude to unalterable intelligence characteristics, the approach is associated with a learnable process.

> In most creative work the best way to court insight is to thoroughly immerse yourself in your problem, to have a clear understanding of the nature of the problem, all its data and all its limitations [. . .]. After periods of unproductive hard work, it is then suggested that you forget the problem completely. [. . .] Suddenly, when you least expect it, a day, a week, or a month later, an answer will pop into your mind. Why and how no one knows, but this is the flash of genius.
> (CE, p. 76)

This description of the flash-of-genius is reminiscent of Wallas' (1926) creative thinking model, which invokes the steps of preparation, incubation, illumination and verification.

Arnold attributes quite different effects to the two types of creativity approaches he distinguishes.

A15) Organized creativity approaches bring about incremental change.

A16) Inspired creativity approaches bring about disruptive change.

"Inspired [. . .] approaches [. . .] are those closely associated with the art of creativity rather than the science. Big leaps in knowledge are apt to occur using these approaches, as compared with the slow but steady step-by step advancement made using organized techniques" (CE, p. 73).

Edwin Land who worked for Polaroid provides an example for the inspired approach.

> His biggest dream was a camera that would give a full color picture in a matter of a few seconds after exposure. In trying to make this big dream come true, he ran into a number of seemingly insurmountable difficulties. So, he stepped down a dream [. . .] and finally settled for the original sepia-toned print that first came on the market. [. . .] At this point he turned the models over to his research staff and they, using the controlled, empirical approach, have made steady improvements of the original invention. [. . .] A large, creative step was made using the big dream approach. This was a functional innovation and looking back through the history of invention, it seems that a large share of the functional changes were brought about in this fashion. Less creative acts, improvements to the big dream, are usually made in a step-by-step fashion, following one or more of the organized approaches.
> (CE, p. 76)

Arnold's categories of organized versus inspired approaches appears to some extent analogous to Maslow's distinction between secondary creativity (where disciplined rule-following yields gradual progress) versus primary creativity (where unconscious, unconventional thinking yields disruptive breakthroughs). This distinction is elaborated in Maslow's CE essay (1959/2016).

D29) Combined creativity approaches use elements from the organized and the inspired approach. Again, Arnold gives two examples, *Serendipity* and the *Scientific Hunch*. "Combining the flash of genius with the controlled empirical approach gives rise to a process that has brought back an old word into popular usage—serendipity—the happy faculty of stumbling upon things of value when looking for something else" (CE, p. 76f.). For this approach, Arnold turns to the mindset of the innovator.

> I believe, like the Greek, Heraclitus, that you never find the unexpected unless you are looking for it. You do not stumble upon things of value unless your mind, at least subconsciously, is prepared to recognize it. You must be sensitive to problems and to solutions; you must be keenly observant and highly associative in your thinking so that these things of value will be recognized when they are seen.
> (CE, p. 77)

Another approach is the *Scientific Hunch*, which Arnold describes "as a combination of the rational approach and the big dream approach. [. . .] It is not wholly rational, for frequently it is nothing more than an emotional feeling, a 'hunch' that such-and-such will occur if I carry out steps A, B, and C" (CE, p. 77).

While the combined approaches mentioned by Arnold merge only one approach from the inspired and organized category each, design thinking appears to systematically combine all of the discussed approaches. It also iterates and advances them.

M5) Design Thinking combines inspired and organized creativity approaches systematically and comprehensively.

Big Dreams, big questions, and big ideas figure centrally in design thinking. However, they are not associated with a random soaring off into space. Rather, a strict emphasis on the "user need" as focal point of attention throughout the whole project continuously provides purpose and orientation. *Insights* are also a key element in design thinking, for example, as part of POV-madlibs (d.school 2010b, p. 21). Methodologically, they are certainly courted by immersive experiences, while setting the problem aside does not appear to be necessary in all cases. An *Empirical Approach* is adopted as design thinkers embrace a "bias towards action". Iterating prototypes can be considered an advanced version of trial-and-error where "errors" become a tool to learn quickly (Roth 2015a; von Thienen et al. 2017). The *Rational Approach* is continued through careful problem statements including How-might-we-questions (d.school 2010b, p. 26), design principles (p. 25), POVs (p. 21) or POV analogies (p. 22).

9 A Theory of Creative Thinking Education and Meta-Cognitive Control

As a visionary educator, Arnold experiments with curricula and reflects upon the beliefs that guide his teaching (cf. Arnold 1953/2016, 1959/2016; Clancey 2016). One central assumption is "that it is possible to materially increase the degree to which one realizes his total potential by understanding, practice, and exercise. The increase can vary from ten percent to several hundred percent" (CE, p. 79).

A17) Creativity education increases creative achievement.

Arnold also believes:

A18) Creativity education increases creative potential.

In particular:

A19) Practicing creativity methods serves to advance creative mindsets.

As part of his method compilation, Arnold explicates numerous beliefs as to which methods help to develop which mindset attributes. “These techniques, when applied conscientiously and repeatedly, will help awaken and strengthen your own creative potential. The checklists, for example, will spur the questioning spirit, and attribute listing and morphological analysis will help develop the powers of observation in the search for generic, basic relationships” (p. 96).

In a manner that very much anticipates present-day design thinking education, Arnold’s courses are intended to endow students with “confidence as well as competence” (p. 71). They shall create enthusiasm for problem-solving and strengthen the creative mindset. Though methods—and gaining experiences in their usage—figure centrally in class, it is anything but a teaching aim to create rigid method users.

A20) Education shall endow students with creative confidence as well as competence—and not with inclinations of rigid method use.

One pedagogical intervention to foster goal orientation rather than rigid method usage is to allocate long periods of time for clarifying problems prior to seeking solutions. This is a pedagogical strategy design thinkers have retained up to the present.

> Creative men [. . .] [spend a] larger proportion of their time [. . .] in reorienting themselves, in searching for problem statements and definitions, in getting a clear picture of what they wanted to do—and a relatively short time in actually carrying out the solution.
>
> This is one thing that I think is typical of people who are goal oriented, rather than technique or method oriented. Most students, for example, if you give them a problem to do [. . .] jump right away into some kind of procedure on how to solve it. They don’t sit down and try to think “What am I trying to do? What is the goal I am aiming for? [. . .]” They start looking for some method. [. . .]
>
> I am sure that if a great deal more time were to be spent in actually formulating a basic, generic, very broad, comprehensive picture of what you are trying to do, one would be much more effective in arriving at an outstanding solution.
>
> (Arnold 1956, p. 28)

In addition, it is a central part of Arnold’s teaching approach to regulate the success and failure experiences students have in class, in order to build up their creative confidence.

A21) Education shall create experiences of success and failure for students, which enhance their creative confidence.

> Properly motivated and willing to take a chance, the creative worker must, in addition, have self-confidence in his own ability to come up with a new and better solution. This is an extremely important emotional attribute and can only be developed through experience and exercise. It has been said that nothing breeds success like success. And this is probably true, but the corollary that failure breeds failure need not be true. If through continued application failures can be corrected, high orders of self-confidence can be developed. Actually, the fear of making a mistake is a very devastating emotional block to creative activity. People should realize that progress is made through failure as well as through success. I have had better success in training creative designers by helping them develop this spirit of self-confidence than I have in imbuing them with special design techniques or tricks of the trade.
>
> (CE, p. 87)

This regulation of experiences has been carefully advanced in the design thinking community. The subject is not only accorded great attention in many design thinking treatises (e.g., Kelley and Kelley 2013; Roth 2015a; von Thienen et al. 2017), it also informs recent discussions on how to define creativity. As part of his *Dynamic Definition*, Corazza (2016) provides a critical discussion and reformulation of creativity criteria such as to acknowledge that a person and her process can be called creative even in the case of failing or otherwise inconclusive outcomes. Creative achievement is only the final outcome for which to aim. Students need to learn how to handle possible frustrations along the way; they are a normal part of creative activity.

Furthermore, a number of additional abilities that Arnold seeks to strengthen in students may be summarized as increased "meta-cognitive control," though he did not use this term himself.

M6) Education shall endow students with meta-cognitive control for creative activity.

D30) In creative activity, meta-cognitive control is the ability to identify and regulate factors that impact creative progress. As an important element of preparation, Arnold highlights that "we must not only study the creative process, but we must also study ourselves as the only creative instrument our species has." That is, like an instrument that generates creative outcomes when calibrated well, students shall learn how to calibrate themselves in order to maximize their creative progress.

One of the ways in which today's design thinking community builds on Arnold's ideas about meta-cognitive control is by providing "mottos" that guide design activity. In Arnold's framework

Meta-cognitive control for creative activity includes

- *Monitoring, regulating and balancing the three thinking modes.* In particular, it is important to dispense judicial thinking during think-up sessions. In the course of the whole creative process, however, mastery of all thinking modes is essential. In present-day design thinking culture, a sample motto that is used to increase meta-cognitive control of thinking modes is "defer judgement" (d.school 2010b, p. 28) as invoked specifically in the first half of the process.
- *Monitoring and carefully selecting communication means.* Here, Arnold differentiates between three types of communication:

> the language of the written and spoken word, the language of symbolic logic or mathematics, and lastly, the language of vision. In order to originate ideas, to preserve them for his own later use, or present them to others, he must use one or more of these languages. The more articulate he is, the greater will be his own efficiency and easier will be his task of convincing others of the merit of his ideas.
>
> (CE, p. 128)

One of the present-day design thinking mottos that continue this theme is "Show Don't Tell [:] Communicate your vision in an impactful and meaningful way by creating experiences, using illustrative visuals, and telling good stories." (d.school 2010b, p. 0).

- *Monitoring and adapting one's creative process including "stages", aims, broadness of scope, pace, and tools.* Using process models for orientation, carefully selecting the broadness of one's design challenge and its content, exhibiting "the ability to change pace" (CE, p. 86), being versed in numerous design methods for all stages of the process or "having many tricks in your bag" (CE, p. 86) are central preconditions for this type of meta-cognitive control. These ideas bear strong resemblance to the design thinking motto "Be Mindful Of Process [:] Know where you are in the design process, what methods to use in that stage, and what your goals are." (d.school 2010b, p. 0).
- *Noticing and overcoming creativity blocks.* In particular, the creative thinker should beware of perceptual, cultural and emotional blocks. One way in which design thinkers continue this line of thought is by highlighting mottos such as "Fail early and often" (Meinel and Weinberg 2013), which in this case should help to regulate a key emotional block, namely fear of failure.

10 The Term "Design Thinking" in Arnold's Framework

While "design thinking" is usually thought of as a rather recent term, it was already used by Arnold. His concept of design thinking resembles the modern one, but is also different in some respects. A similarity is that Arnold, like us today, speaks of design thinking in the sense that people intentionally develop and invent things and design solutions.

D31) Design thinking means to approach the world as a designer who intentionally develops or invents novel solutions.

A difference is that Arnold distinguishes between several kinds of design thinking. He suggests four areas in which developments and innovation can take place. "There are four general areas or fields of design activity. These areas are: (1) increased function [. . .]; (2) higher performance level [. . .]; (3) lower cost [. . .]; and (4) increased salability" (CE, p. 118). To him, design thinking covers all four areas, and projects ranging from small-scale to large-scale. Today, we usually refer to "design thinking" only in the case of large-scale projects in area (1).

When someone pursued a project in the first design area and thus made an increased-function-innovation, Arnold explains that "new needs were filled [. . .] or old needs were satisfied in an entirely new way" (p. 104). The large-scale addition of function amounts to disruptive change: given sufficient scope, functional innovations mean "a large, creative step" (p. 76). By contrast, a higher level of performance and lower costs are typical cases of incremental developments.

D32) A solution is disruptive when it satisfies a formerly unmet need, or satisfies an already addressed need in an entirely new way, and thus creates a large-scale addition of function.

D33) A solution is incremental when it better satisfies an already addressed need in an already established way.

Arnold suggests that flexibility is ideal, i.e., considering all areas of design opportunities.

> It is rather interesting to look over the developmental history of any product or family of products and try to classify the changes into one of the four areas. It might be a good idea for each one of you to do that for your own company's products. Your group, too, might have gotten into a rut and is inadvertently doing all of your *design thinking* in one area and is missing good bets in other areas.
>
> (CE, p. 119, our emphasis)

11 Selected Advancements of Arnold's Creative Thinking Framework and Differences to Design Thinking

Many ideas that Arnold contributed were later picked up and elaborated by his successors. To name just a few examples, a need-based theory of design, visual thinking, relaxation, humour, and playfulness were elaborated by Robert McKim (1959/2016, 1972). James Adams continued consulting activities; he advanced the concepts of creativity blocks and thinking languages (1974). Merging science, engineering and art next to the subject of self-development figured centrally in Faste (1994 and unpublished). Re-designing and studying teamwork, prototyping culture, creative self-confidence and process mastery are some of the key concerns advanced up to the present by Stanford's visionary educators (e.g., Leifer 1998; Kelley and Kelley 2013; Roth 2015a). Katz (2016) picks up philosophical themes.

There are two issues where one might expect a 180-degree-turn from Arnold's creative thinking framework to present-day design thinking. However we will argue that in both cases there is actually a great deal of continuity. Yet, in a third area we do see a major change.

First, design thinkers embrace a bias to action and sometimes express irritation on behalf of their own name. Even the d.school Bootcamp Bootleg (2010b), which is a central method-compilation for the design thinking community, raises this issue upfront. "Bias Toward Action[:] Design thinking is a misnomer; it is more about doing that [sic] thinking. Bias toward doing and making over thinking and meeting" (p. 0). By contrast, Arnold presents a comprehensive framework on the subject of thinking. Yet, Arnold's framework includes strong antecedents of the bias to action. "Without the drive to carry a project through to completion, in spite of all obstacles, the idea has little or no value. This is probably why some research directors have been overheard to say that ideas are a dime a dozen, they want men who are doers not thinkers" (CE, p. 104). Arnold agrees wholeheartedly and this is the reason why he constantly demands that creative thinkers need to make their thoughts tangible. In addition, it is by now very clear that human thought is both embodied and embedded, and as such there is no clear-cut separation between thinking, action and the surrounding environment, while there remains a distinction between abstraction and concrete realization.

Second, Arnold's framework focuses on individuals, while the design thinking community is generally convinced that "innovation is a team sport" (Schar 2011, p. 1). It is indeed true that Arnold's theoretical framework "emphasizes the individual" (CE, p. 78). Yet, his method compilation covers different approaches for creative teamwork in great detail and discloses Arnold's profound personal experiences with them (see also Clancey 2016 for a comprehensive discussion of this subject). In particular, a work approach of the Design Synthesis Group led by William Gordon is elaborated on multiple pages, annotated with personal impressions and bears a striking resemblance to present-day design thinking practices. For instance, Gordon was strongly concerned with the energy-level of teams in think-up sessions.

> There are a number of tricks that can be used to relieve the fatigue. [. . .] Gordon frequently uses one trick which I believe is very novel and effective, and that is to provide one less chair than the number of people attending the session. This means that one man stands or sits on the edge of a desk or even on the floor. Should any man seated in a chair get up to move around or leave the room for any reason the unseated man quickly takes the vacated chair and so there is a continual, though imperceptible movement throughout the session, therefore no one becomes physically or mentally fixed during the three hour period.
>
> (CE, p. 111)

Design thinking continues this concern for "imperceptible movement", such that "no one becomes physically or mentally fixed" and people maintain a high level of energy. However, today's solution seems a little less awkward and thus might be considered more elegant. Teams are provided with high chairs and high tables so that they are standing almost as much as they are sitting; mobile furniture keeps the teams moving (Doorley and Witthoft 2012; von Thienen et al. 2012b). This is one way in which design thinking facilitators manage "the group's performance and energy" (d.school 2012, p. 2) today.

Also, the subject of delaying a search for solutions is deeply engrained in design thinking traditions.

> Bill Gordon felt that the main weakness of the Osborn-type brainstorming sessions was a solution too soon arrived at. Brainstorming starts producing solutions right at the start. To prevent this, Gordon devised a different type of group approach in which only the chairman of the group knows the nature of the problem being discussed [. . .]. Suppose the problem is to find a new way to park automobiles in a crowded city. The subject the chairman might choose to describe the discussion might be "storing things". [. . .] Someone might mention how bees store their honey. Conceivably this could be a possible solution to the problem. Some sort of a honeycomb structure for parking cars, or, another person might say that things are often stored by hanging them up. This might lead to a solution in which cars are hung on hooks like sausages. [. . .] Finally, when he senses that the group is close to the best solution, Gordon reveals the exact nature of the problem. The session is so conducted that by the time the problem is revealed to them, a high level of excitement runs through the group.
>
> (CE, p. 110)

Arnold challenges his audience to advance this methodology. "While I believe Osborn's technique discloses the problem much too soon, Bill Gordon waits much too long, and a compromise of some kind must be arrived at. Both systems have points of extreme merit, and attempts should be made to combine them" (CE, p. 112). Indeed, design thinking seems to offer such a combination. The whole team

knows the nature of the problem right from the start. However, everybody delays a search for solutions until entering the ideation phase in the middle of the process.

Next to a cornucopia of continuing developments, there also seems to be a profound disruption between Arnold's approach and design thinking. For Arnold, innovation education is deeply entwined with an awareness for and development of innovation theory. By contrast, in design thinking the role of theories is commonly much less pronounced; great emphasis is instead placed on the refinement of education practices. By the time design thinking education institutes are founded, the approach is "only" recognized as a successful practice while its theoretical background appears quite invisible. As Plattner, Meinel and Weinberg hold in 2009, "it will remain a task of subsequent publications to submit profound theoretical concepts and conclusive theories that allow for a thorough understanding of design thinking and its components. We expect that the design thinking research program [. . .] will make important contributions in this regard" (p. 8, our translation).

The change in teaching philosophy becomes manifest in the writings that students likely draw on over the years. Arnold's works include extensive theorizing and ample literature references. His successor Robert McKim (1972) offers fewer explicit theories, more exercises and still extensive literature references. The soft systems guide (Koberg and Bagnall 1972) that is occasionally used for education purposes later on reduces the theory content even further; it is very practically oriented and still provides literature references. The Bootcamp Bootleg (d.school 2010b) is exclusively practice oriented and offers no literature references whatsoever. It is prototypical in that it fully does away with theory.

Today, design thinking facilitators design education experiences as much as students learn to design experiences for users (von Thienen et al. 2016b). The "look and feel" of formal school or university education is strictly avoided. Frontal lectures are short and rare (Kelley and Kelley 2013; Roth 2015a). Theories are usually not mentioned at all. Libraries or large collections of books are avoided and even considered a hallmark of "design thinking anti-spaces" (von Thienen et al. 2012b); they would suggest to the student that there is a whole lot to learn and know before (s)he can be a good innovator and thus would seem to antagonize creative confidence and a bias to action. Instead, design thinking education encourages a quick closing of knowledge-gaps through immersive experiences and teaming-up with experts from diverse knowledge domains. Thus, a core teaching belief appears to have changed.

M7) Arnold's Teaching Belief: Creativity education needs to draw on explicit creativity theories.

M8) Common DT Teaching Belief: Creativity education is a practical matter; it does not need to draw on explicit creativity theories.

Amazingly, design thinking education appears to advance creative mindsets—in the sense described by Arnold—even without explicitly invoking theories. In particular, studies on education effects (e. g., Royalty et al. 2012; von Thienen et al. 2016b) show that design thinking trainings elicit a great amount of daringness, drive and creative confidence in students almost immediately, and lasting beyond the completion of classes. What might be a minor downside of the presently embraced

approach of detaching from libraries, literature references, and generally from theories is that, to some extent, the community itself seems to have lost sight of "why and how the Design Thinking method works on a scientific basis" (Plattner 2011, p. v). Calls for balancing context-dependent design thinking knowledge and context-independent knowledge of the traditional sciences are brought up with increasing frequency and insistence (Leifer and Meinel 2015; Mabogunje et al. 2016). We appear to face a pendulum effect here. The disavowal of theory was an experiment to see how far it could go, to understand how and to what extent confidence, enthusiasm, and daringness to try out ideas might be developed first. To be sure, this experiment has been a fruitful one. Education practices have achieved a high degree of refinement. At the same time, theoretical frameworks—at least available on demand—will likely play a greater role again in the future. We believe the optimal point is represented by a personalized balance between sound theoretical foundations and immediate practical tools and methodologies. In the past, theories provided fertile soil. Design thinking practices grew upon scholarly insights and reflections.

Leifer and Meinel (2015) acknowledge the fruits of empirical studies that were launched in the last years. "Now that we have the roots of the scientific comprehension of design thinking we can expect to continuously improve our understanding of ourselves" (p. 3). The authors of this chapter hope that historical design thinking research as reported above can also contribute to this vision.

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