Review Article

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Design Thinking in Education: Perspectives, Opportunities and Challenges

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Abstract: The article discusses design thinking as a process and mindset for collaboratively finding solutions for wicked problems in a variety of educational settings. Through a systematic literature review the article organizes case studies, reports, theoretical reflections, and other scholarly work to enhance our understanding of the purposes, contexts, benefits, limitations, affordances, constraints, effects and outcomes of design thinking in education. Specifically, the review pursues four questions: (1) What are the characteristics of design thinking that make it particularly fruitful for education? (2) How is design thinking applied in different educational settings? (3) What tools, techniques and methods are characteristic for design thinking? (4) What are the limitations or negative effects of design thinking? The goal of the article is to describe the current knowledge base to gain an improved understanding of the role of design thinking in education, to enhance research communication and discussion of best practice approaches and to chart immediate avenues for research and practice.

Keywords: literature review; design thinking; higher education; k12; informal learning; participatory design; LSP; LEGO serious play; making; makerspaces; bricolage; tinkering; library; museum.

1 Introduction

Design thinking comprises a variety of creative strategies for stewarding projects with multiple stakeholders or fostering organizational innovation: *“It helps deal with ambiguities and articulate the right questions, as well as identify and formulate possibilities and potentials”*

(Grots & Creuznacher, 2016, p. 191). As a problem-solving approach that has been tried and tested with socially ambiguous problem settings, it deals with everyday-life problems, which are nonetheless difficult to solve – “wicked problems” (Rauth, Köppen, Jobst, & Meinel, 2010). Wicked problems have no right or wrong solution and resist traditional scientific and engineering approaches, as *“the information needed to understand the problem depends upon one’s idea for solving it”* (Rittel & Webber, 1973, p. 161). Wicked problems have a wide, unbound problem space and complexity, are open for interpretation, surrounded by competing or conflicting opinions for solutions, and unlikely to ever be completely solved (Hawryszkiewicz, Pradhan, & Agarwal, 2015).

Design thinking aims at transcending the immediate boundaries of the problem to ensure that the right questions are being addressed. The process foresees steps that allow participants to analyze, synthesize, diverge and generate insights from different domains through drawing, prototyping and storytelling (Brown, 2009). During the design thinking process, the facilitator encourages learners to see constraints as inspiration (Brown & Wyatt, 2010). The results are typically not directed toward a technological “quick fix” but toward new integrations of signs, things, actions, and environments (Buchanan, 1992).

According to Renard (2014), the term design thinking has roots in various disciplines and is frequently, although not exclusively, associated with engineering, architecture and related design disciplines in early literature focused on design thinking.

The essence of design thinking is to put participants into contexts that make them think and work like an expert designer, and thereby foster civic literacy, empathy, cultural awareness and risk taking (Sharples et al., 2016). According to Skaggs (2018) the tools observation, experience, and inquiry allow designers to understand human needs and shape information to drive the creation of products and experiences that make human connections through aesthetics, need-finding, or making meaning. As awareness of the designed experience increases, so

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does the desire to apply the process of design thinking to a wider range of scenarios to analyze and resolve any business or productivity challenge in a new, insightful, invigorating manner (Hodgkinson, 2013).

While design thinking has captured the imagination of practitioners and educators in a range of fields, this widespread interest has been repeatedly characterized as problematic in the scholarly discourse. Taheri, Unterholzer, Hölzle, and Meinel (2016) stated that, “disparities among experts regarding the general understanding of design thinking, let alone its expected learning outcomes”. Several authors have observed that, despite its popularity, the concept lacks coherent and consistent descriptions (Kimbell, 2011; Taheri et al., 2016; Micheli et al., 2018). The numerous normative and often process-focused depictions of design thinking seem limited in their ability to accurately depict and describe its practice (Carlgren, Rauth, & Elmquist, 2016).

“Design thinking has attracted considerable interest from practitioners and academics alike, as it offers a novel approach to innovation and problem solving. However, there appear to be substantial differences between promoters and critics about its essential attributes, applicability and outcomes”. (Micheli et al., 2018, p. 2)

The lack of conceptual clarity does not slow down the adoption of design thinking in education. For example, Goldman, Kabayadondo, Royalty, Carroll, and Roth (2014) stated that in over 60 US universities and colleges, design thinking is taught through workshops, supplemental training, courses, or degree programs. Similarly, Callahan (2019) observed that design thinking is being used in K-16+ curricula to foster the development of 21st-century skills, championed by the company IDEO and Hasso Plattner Institute of Design. *“Design thinking has become a pedagogical phenomenon in higher education due to its widespread relevance across many disciplines”* (Beligatamulla, Rieger, Franz & Strickfaden, 2019, p. 91).

Where does this fascination stem from and how can it translate into reflective scholarly practice? This article maps the landscape of design thinking in education through a systematic literature review to answer four distinct research questions:

1. What is the potential of design thinking for education?
2. How is design thinking applied in different educational settings?
3. What tools, techniques and methods characterize design thinking?
4. What are the limitations of design thinking?

The goal is to enhance research communication and discussion of best practice approaches.

The article is structured as follows:

- The theoretical overview provides clarification of the term design thinking, and summarizes previous literature reviews and other related work.
- The methodology section delineates the sampling strategy, the development of codes, and the corpus management with Zotero.
- The result presentation is organized along the four research questions.
- The discussion section identifies consequences for educational practitioners and design thinking researchers and contextualizes findings with the results other literature reviews and related work.
- The conclusion summarizes the findings in a concise overview table and offers pointers for research designs and educational best practices.

2 Theoretical Overview

While the concept of design thinking within the academic dialogue of design has been under discussion for more than 30 years, its recent adoption as an innovation method has led to its popularity in various disciplines (Wrigley & Straker, 2017). As Goldschmidt (2017) stated, the term design thinking means different things to different communities. The author distinguishes two facets: (1) Descriptive models of the design process, based on observational research of real-life or laboratory design activities by individuals or teams; (2) a method to be practiced in industries that strive to introduce innovative products or services.

2.1 Terminology

Interest in how designers work and think progressively moved from the purview of designers and architects to the field of management and business administration (Elsbach & Stigliani, 2018). Both communities emphasize iterative processes, collaboration, speed of concept modeling and testing through prototyping, and interaction with users. However, as Goldschmidt (2017) emphasized, the difference between cognitive models and facilitation methods should not be overlooked. Similarly, Wrigley and Straker (2017) note a shift from discussing and studying design thinking as cognitive processes designers use, to

a specific way in which non-designers evaluate and use design methods – a shift “from design as a science to design as a mindset” (Wrigley & Straker, 2017, p. 2). Johansson-Sköldberg et al. (2013) describe this difference in terms of “designerly thinking” vs. design thinking:

“A simple way of discussing the discourse of design thinking is as two distinct discourses: One we call ‘designerly thinking’. This refers to the academic construction of the professional designer’s practice (practical skills and competence) and theoretical reflections around how to interpret and characterize this non-verbal competence of the designers. [...] The other discourse is ‘design thinking’. We reserve this term for the discourse where design practice and competence are used beyond the design context (including art and architecture), for and with people without a scholarly background in design, particularly in management. ‘Design thinking’ then becomes a simplified version of ‘designerly thinking’ or a way of describing a designer’s methods that is integrated into an academic or practical management discourse.” (Johansson-Sköldberg et al., 2013, p. 123)

Elsbach and Stigliani (2018) describe design thinking as an approach to problem solving that uses tools traditionally utilized by designers of commercial products, processes, and environments. According to Cochrane and Munn (2016) the three main elements of design thinking are observational research, visual sense making, and rapid prototyping. The authors describe a typical design thinking process as a cycle of (1) empathizing and observing, (2) defining the problem, (3) creating ideas, (4) prototyping, and (5) testing (Cochrane & Munn, 2016).

Design thinking has been recognized repeatedly for its contributions to business and management practices. This has led to an increase in the number of higher education programs that teach design thinking to business students, managers and executives (Matthews & Wrigley, 2017). In order to be marketable and competitive, students need to understand, embrace and generate innovation by developing and implementing new and meaningful ideas (Wright & West, 2010). Moreover, even the design discipline recognizes that the procedural knowledge of design thinking might be more important than the actual design skills – “the survival of design as a profession may depend less on traditional design education and more on responding strategically to contemporary changes, influenced by ethical and environmental issues as well as technological advancements” (Cassim, 2013).

In the context of this article, I follow a similar view of *design thinking as a process and mindset*, specifically positioned to address *wicked problems* in line with the rich descriptions by von Thienen, Meinel, and Nicolai (2014):

“Design thinking offers ample help to solve wicked problems of a liberal type where you may fail and experiment first to become all the more successful later on. It does so by establishing mindsets and offering tools which save you from the impossible task of finding ‘the correct problem view’ or ‘the optimal solution’. Instead, attention is drawn to needs which await their fulfillment. New interpretations of the problem are advanced which take into account the perspectives of different stakeholders and which help to look at the matter from a new angle – since the old problem views turned out to be blind alleys. Finally, a lot of tools are provided to propel the process of problem solving in a productive direction – making sure the process remains flexible, jaunty and unrestrained by arbitrary formalizations.” (von Thienen et al. 2014, p. 105)

2.2 Previous Work

This article expands upon several previous literature reviews in the design thinking field:

Razzouk and Shute (2012) conducted a systematic review of 45 documents to answer three questions: (a) What are the characteristics of design thinking, (b) what are the differences between a novice and an expert design thinker, and (c) why is design thinking important?

Their literature review focuses on the characteristics of what this article references as “designerly thinking”, i.e., the authors analyzed the typical studio processes and mindsets of designers and architects. The authors highlight the following design-thinker characteristics: (1) Human- and environment-centered concern, (2) ability to visualize, (3) predisposition toward multifunctionality, (4) systemic vision, (5) ability to use language as a tool, (6) affinity for teamwork, (7) avoiding the necessity of choice. Similarly to Lor (2017), the authors stress the importance of design thinking for promoting problem-solving skills students need to succeed in the 21st century: “*Helping students to think like designers may better prepare them to deal with difficult situations and to solve complex problems in school, in their careers, and in life in general*” (Razzouk & Shute, 2012, p. 344).

Johansson-Sköldberg, Woodilla, and Çetinkaya (2013) conducted a literature review of both “designerly thinking” and “design thinking” with the goal of uncovering trends, recognizing important authors to follow, and appreciating differences in how the concept has been treated in the academic and non-academic press. The literature base of their research consisted of 168 items, comprised of academic articles, books and blogs / other social media. Their analysis resulted in four different research themes that center around designerly thinking and three different practice themes that are relevant to the role of design thinking in the business world. The research

themes offer different lenses on designerly thinking as “Creation of Artefacts”, “Reflexive Practice”, “Problem-Solving Activity” and, lastly, “Practice-Based Activity and Way of Making Sense of Things”. The three main ways design thinking is characterized in the business context are, according to the authors, (1) IDEO’s Way of Working with Design and Innovation (2) Way to Approach Indeterminate Organizational Problems, and a Necessary Skill for Practicing Managers (3) Part of Management Theory.

Lor (2017) conducted a review and analysis of 68 journal articles, books and reports on design thinking, with a particular focus on its application in education. The corpus was based on literature searches in a number of databases (ProQuest, EBSCO, Springer Link and Google Scholar) using the keywords “Design Thinking” and “Education”, and included sources from the years 2005 through 2016. According to Lor (2017), design thinking as applied in education can be narrowed down to three dimensions: (1) design thinking in curriculum design, (2) design thinking as a teaching-learning approach, (3) teacher training & support for design thinking. The author focuses the analysis specifically on the 21st century skills model as part of the K12 education reform agenda by the Department of Education in the Philippines.

Elsbach and Stigliani (2018) conducted a systematic review that focused on empirical research providing insight into how design thinking relates to organizational culture. Their literature base comprised 86 empirical articles (i.e., including data in the form of case studies, surveys, interviews, and archival documents) that related design thinking and culture. Their review revealed three insights about the relationship between design thinking tools and organizational cultures. First, they found that the effective use of design thinking tools in organizations had a profound effect on organizational culture. Second, they found that organizational cultures influenced (both positively and negatively) the use of design thinking tools. Third, they found that using design thinking tools produced both physical artifacts (e.g., prototypes, drawings, design spaces) and emotional experiences (e.g., the experience of empathy or surprise/delight).

Micheli, Wilner, Bharti, Mura and Beverland (2018) conducted a systematic review of 104 articles that were identified based on search of four databases (ProQuest, Business Source Premier, Science Direct and Emerald) for the years 1985 to 2017. This review concentrated on design thinking in management discourse. Therefore, articles where design thinking had been applied to other fields of inquiry were not included. The authors identified ten principal attributes of design thinking in the management

context: (1) User-centeredness and involvement, (2) Problem solving, (3) Iteration and experimentation, (4) Interdisciplinary collaboration, (5) Ability to visualize, (6) Gestalt view, (7) Abductive reasoning, (8) Blending analysis and intuition, (9) Tolerance of ambiguity and failure, (10) Creativity and Innovation. Finally, the authors deployed a cluster analysis to identify avenues for future research. Themes they discovered within the literature were “interdisciplinary collaboration”, “reclaiming design thinking as designers’ domain”, “resilience in problem solving”, “seeing and reflecting upon the whole”, “learning to think like a designer”.

McLaughlin, Wolcott, Hubbard, Umstead and Rider (2019) conducted a qualitative review of 15 articles related to health profession education after scanning 169 sources with “Design Thinking” in the title. They identified two purposes for the use in education (a) enhancing creativity and innovative thinking skills of individuals, (b) informing curricula and programs.

In addition to literature reviews, other scholarly endeavors geared to develop a systematic view of the field in business and design thinking education. Three international qualitative interview studies were particularly influential for this article:

Carlgren et al. (2016) conducted an interview study in six large companies, which led to the development of a framework structure and the identification of five themes characterizing design thinking practice in businesses: User focus, Problem framing, Visualization, Experimentation and Diversity.

Rauth et al. (2010) conducted a total of 17 semi-structured interviews with teachers in design schools in Stanford (USA) and Potsdam (Germany) in order to find out more about the underlying methods and mechanisms of design thinking education. Their analysis identified different competencies as a result of design thinking education, such as prototyping skills, emotional skills, capability of adopting perspectives, empathy and a certain mindset. The development of these creative competencies culminates in the acquisition of creative confidence, which assures the students of their own ability of acting and thinking creatively.

Camacho (2018) conducted a qualitative interview study focused on uncovering commonalities and variations among effective approaches of design thinking, based on interviews with twelve global experts. The project captured the convictions of experts at the forefront of design thinking research and practice, and identified three basic traits of design thinking as system-oriented, human-centered, and creation-based.

2.3 Related Approaches

To understand the place design thinking occupies in the scholarly community, it is essential to map its interconnections to fields of inquiry and communities of practice with similar methods, goals or areas of applications.

Participatory Design is an approach that involves the users of a product early on in the development process. Related to the theoretical framework of activity theory, participatory design techniques expose the intricate mix of activities users engage in, reflecting the complexity, flexibility, and social nature of each activity (Kaptelinin & Nardi, 2012). Instead of being a research subject, people are given influence and room for informing, ideating, and conceptualizing in the early stages of the design process (Sanders & Stappers, 2008). As design thinking typically highlights user-centered design and empathy, the tradition of participatory design plays a significant role in understanding design thinking, particularly as it applies to HCI-related projects and the instructional design of educational technology (cf. Panke, Allen, & McAvinchey, 2014; Panke, 2016; Fabri, Andrews, & Pukki, 2016).

Bricolage (sometimes referred to as tinkering) means to engage in a dialogue with a heterogeneous collection of materials and tools, in which items are repurposed and rearranged to solve a problem (Sharples et al., 2014). Bricolage comprises tools and artifacts that were accumulated over time. This may include material that was collected without any specific purpose, and picked up simply because it might be useful someday; as well as outcomes, products or “leftovers” from other projects. The typical bricolage setting is one of constant remix: Its tools and artifacts are not limited to one single use, nor does the user need specialized expertise to adapt and deploy them. Bricolage does not necessitate having a clear end in sight. On the contrary, it requires the stakeholders to be open and start with a vaguely defined idea. This characterization aligns with the open-ended nature of design thinking, and indeed, the interconnectedness of both concepts has been explored in the literature on designerly thinking (Louridas, 1999).

Making is characterized by a specific mindset geared towards tinkering with confidence: Makers understand that it takes time and effort to build something, and do not view a lack of success as a failure (Vaughn, 2018). *“Design thinking, design process, and the value of making things by hand have gained much popular interest in recent years. The renewed interest in making is due in part to the DIY (do-it-yourself) movement and the Maker Faire phenomenon, which offer enthusiasts of many stripes the opportunity to*

exercise their creative capacities” (Renard, 2014, p. 415). According to Brown (2018), the inclusivity of making is strongly characteristic of its rise as a diverse movement of space and belonging. Maker-culture in community and library spans the potential chasm between traditional skills such as crafting and knitting, preserving and upcycling, adjacent to technology and maker expos to learn coding, programming and robotics (Jordan & Lande, 2016). Design thinking and making share elements of rapid prototyping and testing a design, as well as iterating on a design across multiple revisions. Despite these similarities, Vaughn (2018) stresses that they form two distinct discourses. Design thinking and making are connected in multiple ways: First, makerspaces are informal learning spaces in which design thinking activities can be conducted. (2) Design thinking as a mindset is frequently conceptualized similarly to the making mindset. (3) Design thinking and making share similar processes. (4) Design thinking is often conceptualized as part of making: *“The hands-on, learning-by-doing experiences afforded by makerspaces implicitly require a design approach to problem solving”* (Bowler, 2014, p. 60). Jordan and Lande (2016) describe this as *“additive innovations”*.

LEGO Serious Play (LSP) is a collaborative, creative method that uses LEGO blocks and figures to develop scenarios for organizational development, conflict resolution or web design (Cantoni, Marchiori, Faré, Botturi, & Bolchini, 2009). The method aims at improving group problem solving, shared learning, listening and collaborating by making and creating. In a typical serious play session, participants start with a few warm-up exercises to learn how to stimulate different types of imagination, by using LEGO constructions as metaphors for the real world. The serious play process results in constructions of how individuals perceive their entire organization, and ultimately, of how a particular strategic challenge should be dealt with (Roos & Grey, 2004). A variety of design thinking use cases involve LEGO bricks (cf. Jensen, Seager, & Cook-Davis, 2018; Panke et al., 2014; Panke 2016). Beyond the physical objects, design thinking and LSP share the creed that playful activities can have serious outcomes and inform strategic decisions.

3 Methodology

In the past decade, design thinking has transcended the boundaries of business and management education as well as the contexts of the seminal design thinking schools (i.e. Stanford d.school, Hasso Plattner Potsdam). This literature review uses an approach distinct from

prior work by focusing on the pedagogical opportunities of design thinking, reflecting upon its application in different subject areas, formal and informal learning, K12 and higher education. It is a systematic extension of previous reviews with a purposefully organized literature base that serves as platform for future research on design thinking for education.

In line with the objective of creating an overview that synthesizes research themes, topics, questions, approaches and findings, this review focused on broad, thorough data collection and careful analysis (Levy & Ellis, 2006; Webster & Watson, 2002). With an educational twist, the approach is aligned with the purpose statement that Micheli et al. (2018) developed for their systematic literature review: *“to shed light on current knowledge and conceptualizations of design thinking in order to identify its principal attributes, highlight relevant issues and tensions in the literature, and advocate for further studies to advance theory and practice”*.

Systematic literature reviews employ a transparent and reproducible procedure for selecting, clustering and summarizing the material (Keele, 2007). To gather the text corpus, researchers may follow different approaches, for example using a panel of experts to identify relevant papers; using knowledge of the existing literature to select articles; or searching various databases using keywords (cf. Crossan & Apaydin, 2010). I modeled my approach on the work by Elsbach and Stigliani (2018) by selecting articles for review on the basis of a combination of protocol-driven methodology with a defined search strategy and a snowballing technique that allowed the corpus to evolve as the study unfolded.

The corpus for this review is based on systematic keyword searches in the indexes ERIC (<https://eric.ed.gov/>), LearnTechLib (<https://www.learntechlib.org/>), SCOPUS (<https://scopus.com>), Web of Science (<https://apps.webofknowledge.com/>) and Google Scholar (<http://scholar.google.com>).

- **LearnTechLib:** The AACE digital library LearnTechLib includes proceeding from hundreds of AACE and SITE conferences, articles from AACE journals as well as abstracts from other content partners. In addition, it indexes e-books, reports, dissertations, videos, keynote talks, presentation slides and webinars.
- **ERIC** is an online library of education research and information, sponsored by the Institute of Education Sciences (IES) of the U.S. Department of Education. The database ERIC is a free resource, and allowed for filtering the results of the query by educational sector.

- **Google Scholar:** Launched in 2004, Google Scholar is an academic search engine that uncovers a tremendous amount of research literature that is typically hidden in the deep web (Zientek, Werner, Campuzano, & Nimon, 2018). However, vast volume of results are both the strength and weakness of Google Scholar for the purpose of a systematic literature review, since it can lead to an unmanageable amount of sources (Panke, 2018b). When leveraging Google Scholar it is advisable to either have a narrow timeframe, specific keywords or a stop rule.
- **ECDTR:** The “Electronic Colloquium on Design Thinking Research” (ECDTR) by Hasso-Plattner Institute, Potsdam, Germany is a collection of papers, short notes and surveys with relevance to design thinking research. Submissions to ECDTR are peer reviewed, but do not preclude future submission to any conference or journal: the submissions in the archive have the status of technical reports. I specifically used this repository to add theses and reports to the corpus.
- **ResearchGate:** ResearchGate is a social networking site for researchers to share papers, ask and answer questions, and find collaborators. The community was founded in May 2008. Registered users can create a profile and add their publication records as well as full texts. If copyright permits it, the full text can be publicly accessible, otherwise authors can upload a private copy. In addition, researchers can use contact features to request a full text from a colleague. First and foremost, ResearchGate was developed as a way to support access to scholarly work (Panke, 2018a). I used the platform both as a way of extending our access to full texts, as well as researching the latest developments.
- **SCOPUS and Web of Science:** The academic catalogs Scopus and Web of Science allow users to analyze searches in order to identify the most cited research, the chronology of publications and citations, and the major disciplines within a topic.

The search queried for articles that referenced ‘Design Thinking’ in the title and focused on sources from 2009-2019 (November)¹. The time frame selected covers the vast majority of design thinking publications, in particular when focusing on its application in non-studio disciplines:

¹ Three sources were outside the timeframe, but included for their relevance. Articles published past November 30th 2019 were not included in the corpus.

Figure 1: Corpus “Design Thinking in Education, Number of Publications per Year”.

Analyzing search results in the catalog SCOPUS going back to 1994 revealed that 96% of articles on the topic have been published since 2009 and 70% since 2015. Figure 1 depicts the timeline of publications in the corpus.

While the criteria of including the phrase “Design Thinking” in the title of the article may have resulted in the exclusion of potentially relevant sources, this was counteracted by the snowball strategy that relied on cited sources as well as additional content knowledge of the field.

Overall, it proved worthwhile to combine and contrast analyses from multiple tools, as the results will vary, depending on the catalog. The strength of this research is a robust corpus, that is available as open data so that the analysis and findings are open to re-analysis and extensions by other researchers².

For the analysis of the data, I used Zotero 5.0 as a bibliographic management tool. All articles were organized in a Zotero collection. Since the collection comprised searches and imports from different source catalogs, the first step was to consolidate duplicate entries. Next, I excluded articles that were chiefly focused on subject matters outside education. This process resulted in a corpus of 175 items. Additionally, I curated articles that reflected the nature, history and trajectory of design thinking as it pertains to education in six separate collections: (1) Mindset, (2) Models, (3) Process, (4) Theoretical Foundation, (5) Designerly Practice, (6) Designerly Thinking.

I used the extension “zotfile” to extract notes and comments from the PDF and attach these notes to each article. To generate an initial descriptive analytics, I used the Zotero add-on “Voyant Export”. This allowed me to explore the corpus using the online tool Voyant (<https://voyant-tools.org/>): 167 documents were available as full-text, which amounted to 874,979 total words and 44,492 unique word forms. Voyant served as proof of concept to ensure that the corpus contained design thinking articles that focused on learning, teaching and education. Figure 2 depicts the 25 most frequent terms in the corpus.

For further analysis, I added sub-collections as well as tags for the classification of sources that served as in-vivo codes to organize the literature into themes. Since the goal was to consolidate conceptual ideas rather than statistical data, the resulting approach is a qualitative analysis of the material that includes a descriptive overview of the information. I used concept maps, specifically cmap (<https://cmap.ihmc.us/>) for topic reduction (Cañas, Novak, & González, 2004).

The majority of sources in the corpus are journal articles (131), followed by conference proceedings (30), book chapters (7). Almost all empirical accounts of design thinking practices were in the form of case studies, predominantly single case studies, and only occasionally spanning different contexts or institutions. Typical data sources were observation and interviews, analysis of artifacts produced in the design thinking process and survey evaluation. Most applications of design thinking were situated in higher education (81), followed by K12 (34) and informal learning / professional development (20).

² The corpus is available in Zotero format and the bibliography as an XML file at <https://dataverse.unc.edu/dataverse/panke>

Figure 2: Voyant Visualization, interactive display at <http://bit.ly/designthinkingineducationvoyant>.

4 Results

The results section provides an overview of what insights the body of literature included in the review yielded for the four main questions addressed in this article: (1) What are the characteristics of design thinking that make it particularly fruitful for education? (2) How is design thinking applied in different educational settings? (3) What tools, techniques and methods are characteristic for design thinking? (4) What are the limitations or negative effects of design thinking?

4.1 R1: What is the potential of design thinking for education?

What are the traits and effects of design thinking that make it particularly fruitful for education? In other words: Why are educators excited about design thinking in the first place? This is a crucial question, because the debate about whether or not design thinking is effective in education depends upon clarity as to what the goals

are. It is important to distinguish between breaking down the learning outcomes of teaching design thinking and the outcomes of embedding design thinking in educational settings. As Taheri et al. (2016) stated, *“it is time to raise the question: What people learn as a result of taking part in a design thinking training? What are the expected learning outcomes of design thinking?”* (Taheri et al., 2016, p. 2). This literature review aims at capturing and clustering varied learning outcomes *beyond* becoming a design thinker. I approached this goal by reviewing (1) reflections of the nature/history/scope of design thinking and “designerly thinking”, (2) empirical studies of the design thinking process, (3) case studies of design thinking in education. The results indicate clearly that various characteristics of the design thinking process and mindset align with different educational goals. There is no single rationale for using design thinking in education. Instead, different settings will provide specific advantages.

Encouraging Tacit Experiences: Jacobs (2016) discussed how constructing of physical analogues can be productive for strategy work by turning issues into

“embodied metaphors”. These concrete artifacts can then spark debate from a variety of perspectives. Design thinking encourages participants to think with their hands and bodies. As Jacobs (2016) put it: “*if the hand is a window on to the mind, how can we better involve manual practice in the development of strategy?*” (Jacobs 2016, p. 133). As Groth (2017) pointed out, design processes include embodied knowledge even in the planning stage, since designers need to create mental images of the physical objects they intend to create. Making may be seen as a way of negotiating meaning through interaction between the embodied mind and the material environment, thus affecting intrapersonal growth in educational settings. Having a tangible representation allows teams to interact with it and exchange views on it (Camacho, 2018). The shared stories and metaphors triggered by models and artifacts facilitate the development of a shared vocabulary and memorable learning experiences (Jacobs, 2016).

Increasing Empathy: Design thinking allows developers to embrace “the blurred space of social ambiguity” with the purpose of making outcomes more innovative (Lindberg, Meinel, & Wagner, 2011). Bross, Acar, Schilf, and Meinel (2009) describe design thinking as “*a human-centered systems thinking approach that creates experiences for stakeholders by matching human factors with technological feasibility and business viability*” (p. 904). The interview study by Carlgren et al. (2016) revealed that empathy is key to the user-focus of design thinking: “*Empathy was stressed as important and, in order to empathize, different principles/mindsets were seen as crucial: being open, avoiding being judgmental and being comfortable around people with different backgrounds and opinions*” (Carlgren et al., 2016, p. 46).

Reducing Cognitive Bias: Liedtka (2015) discussed design thinking as a method to reduce cognitive bias. According to her analysis, design-thinking practices carry the potential for improving innovation outcomes by mitigating an established set of cognitive flaws: people often project their own world view onto others, limit the options considered, and ignore disconfirming data. While the author analyzed nine different types of cognitive bias in detail, she also offered three distinct general categories of cognitive bias. In the context of inclusiveness, Liedtka’s first category of biases that relate to decision-makers’ proclivity to become trapped in their own world view is specifically meaningful. It comprises the following tendencies:

- Projection bias: People have a tendency to project their past experiences and thus over-estimate the extent to which the future will resemble the present.
- Hot/cold gap: People’s emotional state, whether emotion-laden (hot) or not (cold), unduly influences their assessment of the potential value of an idea.
- Egocentric empathy gap: People consistently overestimate the similarity between what they value and what others value.
- Focusing illusion: People tend to overestimate the effect of one factor at the expense of others, overreacting to specific stimuli, and ignoring others.

According to Liedtka (2015), a remedy for category 1 biases is to improve decision-makers’ ability to imagine the experience of those other than themselves, even in the absence of first-hand data gathering.

Promoting Playful Learning: The 2019 Innovating Pedagogy report (Ferguson et al., 2019) highlights playful learning as a trend, emphasizing the role of play beyond K12 environments, at universities and in continuing education. Play should remain a central component of teaching and learning throughout life. Playful learning flourishes in spaces that are safe, foster exploration and support productive failure, such as design thinking. Watson (2015) described student reactions to design thinking in terms of playfulness, creative expression and joy: “*I hear them talking about using Design Thinking to make sense of ambiguity, to empathize with others, to think creatively, to communicate ideas, to collaborate, and to make people laugh*” (Watson, 2015, p. 18).

Creating Flow / Verve: Primus and Sonnenburg (2018) conducted an empirical study to investigate flow experience at the individual and group level during a one-day design thinking exercise. Their findings showed that (a) the elements of individual and group flow experience were prevalent and highly correlated in the design thinking activities and (b) the nature of the design thinking task had an impact on the flow experience. Design Thinking also enhances the motivation to tackle difficult tasks and stay focused during the process. According to von Thienen, Royalty, and Meinel (2017), students experience *design thinking verve* when they are excited about their projects, work fast-paced, leave their comfort zones, allow for productive failure, trust the process, and share amazement.

Fostering Inter/Meta-disciplinary Collaboration: Multidisciplinary teamwork is a key requirement in the design thinking approach to innovation (Sonalkar, Mabogunje, Pai, Krishnan, & Roth, 2016). The approach seeks to bring together different areas of expertise and leverage concepts and tools sets from each domain to analyze, synthesize, and generate insights and new ideas (Melles, Howard, & Thompson-Whiteside, 2012).

Functional teams are essential for design thinking's effectiveness, and design thinking methods are geared towards reinforcing the significance of managing communication and emotion among team members (Camacho, 2018). This allows for diverse teams to function productively, and to break down boundaries: *"One of the key characteristics of the project was the way in which it actively sought to break down boundaries between design, academia, and museums"* (MacLeod et al., 2015, p. 338).

Inducing Productive Failure / Increasing Resilience: Design thinking encourages participants to see constraints as opportunities. As such, design thinking can create resilience in the face of failure and uncertainty (Micheli, Wilner, Bhatti, Mura, & Beverland, 2018). As Leverenz (2014) stated: *"We must find a way to turn students' fear of failure into excitement at the chance to experiment"* (Leverenz, 2014, p. 9). In the process of working out a solution design thinking allows for many trials and many errors: *"Failures are prized as highly valuable resources: If only embraced and analyzed with an open mind, failures are expected to aid learning, ultimately in the service of even greater creative achievements"* (von Thienen, Meinel, & Corazza, 2017, p. 5). Core mottos of design thinking such as fail fast, fail early, favor action over inaction and embrace experimentation reflect the emphasis on learning through trial-and-error (von Thienen et al., 2014). Participants are encouraged to embrace failures, to learn from them and iterate based on the results. This translates into the habit of giving up ideas and readily changing approaches rather than defending the initial or existing structure when, for example, users give negative feedback (von Thienen, Meinel, & Corazza, 2017). Participants in design thinking activities acquire transferable skills in dealing with uncertainty (Badwan, Bothara, Latijnhouwers, Smithies, & Sandars, 2018).

Producing Surprising and Delightful Solutions: According to Elsbach and Stigliani (2018) the use of design thinking tools can result in emotional responses of surprise and delight. Stakeholders are excited about design thinking because its results significantly differ from expected solutions: *"Design is what it is because it surprises us; and good designs surprise us by their ingenuity and their handling of contingencies"* (Louridas, 1999, p. 534). Goldman, Kabayadondo, Royalty, Carroll, and Roth, (2014) described this as *"the resolution of conflict between a sticky problem and an elegant solution"*, as team members negotiate what is known and unknown, what end-users say and what they really mean, and what does and doesn't work for users (Goldman et al., 2014, p. 33).

Nurturing Creative Confidence: Creative confidence is nurtured when people have the opportunity to think like a designer (Bowler, 2014). Design thinking offers non-designers the chance to act with creative confidence, and perceive themselves as part of creating a more desirable future, with the ability to take action when faced with a difficult challenge (Munyai, 2016). As Carroll et al. (2010) observed: *"design thinking fosters the ability to imagine without boundaries and constraints. This is critical, as the development of creative confidence is an essential part of learning"* (Carroll et al., 2010, p. 52). Design thinking allows students to acquire and experience creative mastery by providing a creative problem solving process, creative work-spaces and collaboration in multi-perspective teams (von Thienen, Royalty, & Meinel, 2017).

Summary: Tacit experiences, increased empathy, reduced cognitive bias, playful learning, flow, collaboration, productive failure, surprising solutions and creative confidence: The potential motives for integrating design thinking in educational experiences are manifold. The multifaceted goals and outcomes associated with design thinking are a key factor in the attractiveness: *"It is this capacity of design thinking to complement existing pedagogies and provide inspiration for change and innovation"* (Melles, Anderson, Barrett, & Thompson-Whiteside, 2015, p. 192).

For a field that is chiefly driven by case study research, it will enhance clarity if the intended purposes as well as unintended outcomes are documented and discussed in context. Design thinking outcomes can be measured along the different dimensions identified in this review: Did learners experience flow? Did they recognize play as part of learning? Were they able to overcome cognitive bias? The answers will likely vary based on the methods, tools and techniques, as well as the participants and settings. The themes identified in this review offer a systematic template for describing the goals and evaluating the outcomes of design thinking.

4.2 R2: How is design thinking applied in different educational settings?

After exploring why educators might want to use design thinking, this section delineates how it translates into educational practice. How is design thinking applied in different educational settings? Educational use cases are manifold: Design thinking techniques have been applied by researchers, teachers, instructional designers, librarians, makers, developers and administrators

with various subject matter backgrounds and interests. The areas of application for design thinking span K12, higher education, informal learning and post-graduate professional development.

4.2.1 K12

The majority of design thinking projects in K12 focus on STEM and STEAM education. The sample also included two case studies in geography. Other areas of application are educational leadership, counseling and the development of tools and services. Several articles focused on the role, perspectives and experiences of teachers.

Innovation in Leadership, Counseling and Diversity: In a theoretical reflection Gallagher and Thordarson (2018) stressed the potential of design thinking for school leadership development, school-wide projects, and initiatives. As an example, Fouché and Crowley (2017) described a school-wide “Innovation Lab” for grades K-4 that engaged students in design thinking activities as a problem-solving approach. Other projects seek to impact the school-wide mission through metacognitive awareness and transition support: Yeager et al. (2016) used design thinking as a methodology for redesigning and tailoring initial interventions for shifting from fixed to growth mindsets during the transition to high school. Fabri, Andrews and Pukki (2016) used design thinking to engage autistic students in participatory design of an online toolkit that offered support for their transition into higher education. Similarly, Suzianti and Atthousi (2019) co-developed a game-based learning environment for hearing-impaired elementary students with design thinking techniques to increase user participation.

STEM / STEAM: Reflecting on the use of design thinking in an art class, Watson (2015) stressed that “*Design Thinking has an important role as a bridge within STEAM education*” (Watson, 2015, p. 18). Multiple examples support this view. Douglass (2016) shared ideas and techniques to enhance science teaching and described how kindergarten students gained a foundation for integrating science and engineering through design thinking. Gross and Gross (2016) described the use of the design thinking process for creating interactive sculptures created in an elementary STEAM club, moving from cardboard prototypes to programming with Scratch. Fouché and Crowley (2017) described how second graders used design thinking to create prototypes that prevent baby goats from escaping from the pen, gaining transferable problem-solving skills. Cook and Bush (2018) characterized design thinking as an opportunity

to expand learning goals beyond the different subject areas of STEAM: “*it provides a vehicle through which a true transdisciplinary learning experience can occur – where students are passionately invested in solving problems as they strive to make the world a better place*” (Cook & Bush, 2018, p. 102). Carroll (2014) described a case study in which university students worked with underserved middle school students as mentors in a STEM-based afterschool program. Both the mentors and the middle school students learned design thinking together. The shared experience allowed the university students to learn how to become a mentor, how to develop user-centered learning experiences, and how to share these experiences with middle school students. Motschnig et al. (2019) analyzed the educational intervention MadeByKids, that included a series of workshops and design challenges at 17 schools with children aged 7-12. The workshops were developed by adopting the *Stanford Design Thinking Method for Kids* with the goal to enhance computational thinking as well as collaboration skills. The authors observed that generally the participants did not seem to have problems acquiring digital competencies, while a lack of teamwork skills affected the project outcomes in some of the groups.

Geography: Anderson (2012) described a case study of elementary and middle school students who used design thinking to examine issues with living in rural and remote areas. The students subsequently designed illustrative multimedia presentations or computer games. Carroll et al. (2010) conducted a qualitative study that focused on the implementation of a design curriculum by a team of university instructors and graduate students during a middle school geography class in a public charter school serving grades K-3 and 7-8. The instructional goal of the project was to use design thinking to teach students about systems, an important element of geography. The students worked in teams through the design process to identify and redesign systems that existed at their school, such as the parking lot or the cafeteria.

Interdisciplinary: Aflatoony, Wakkary, and Neustaedter (2018) facilitated a design thinking course for 39 students from grades nine and ten, aged 15-16. Their evaluation focused on increased skills in problem solving, human-centredness and collaboration. Their findings indicate that while students varied in their engagement with activities skills’ enhancements, all participants improved to a certain degree: “*students clearly showed that their focus shifted towards people, people’s interactions and people’s activities*” (Aflatoony, Wakkary, & Neustaedter, 2018, p. 452).

Perspectives of Teachers: Several publications reflect upon the roles and perspectives of teachers during

design thinking. Retna (2016) conducted a qualitative case study research in a school using teacher narratives. Data includes in-depth face-to-face interviews and participant observation. The findings show that teachers perceive that design thinking holds the potential for enhancing skills such as creativity, problem solving, communication and team work as well as empower students to develop empathy for others within and beyond the community. Carroll et al. (2010) observed: *“It is essential to have teachers see the value of design thinking in their classrooms, and the connection between design and the academic goals of the classroom needed to be obvious to them”* (Carroll et al., 2010, p. 50). Similarly, Kwek (2011) conducted a qualitative case study at a US public middle school partnering with the Stanford d.school to explore the factors that influenced the way design thinking is used in classroom and how it intersects with academic content. Through interviews with school leaders and classroom observations, the study found that mastery of academic core content still drives how design thinking is used to intersect with classroom learning.

4.2.2 Informal Learning

Libraries, makerspaces, museums and zoos are examples of informal learning spaces that are touched by design thinking projects. The connection can occur in three different ways: First, informal learning spaces offer room for design thinking activities, and professional staff can take on the role of facilitators. Second, design thinking activities can be used to rethink exhibition spaces and user experiences. Third, design thinking can be used in a service learning context, where students apply design thinking to enhance museum experiences.

Extending Library Exploration: Bowler (2014) pilot tested a design thinking and maker experience with Library and Information Science (LIS) students, some of whom are training to be school librarians, at the University of Pittsburgh. These students participated in the Bots and Books Design Challenge, an extra-curricular event held each spring during the School of Information Sciences iFest. Working in teams of two or three, students were challenged to select a children’s story and interpret it through a robot, developed with Hummingbird controller and visual programming language. The robots were then judged by a panel of faculty and one librarian from the Carnegie Library of Pittsburgh. In a similar project for a different age group, Coleman (2016) incorporated the design thinking process into literature exploration in the school library. The focus of the first-grade design thinking

challenge was to gain a deep understanding of the elements of the “Three Little Pigs” fairytale by designing a better house for the pigs. The goal was to have students look more deeply than usual at the characters, setting, problem, and solution in the story to develop narrative awareness that they could transfer to their own writing.

Designing museum exhibitions: Design thinking is used as a technique to optimize informal learning spaces for better user experience and learning outcomes. MacLeod, Dodd, and Duncan (2015) described the process of using design thinking techniques in a cross-disciplinary team to address specific shortcomings of an exhibition space: *“the team was able to take each aspect of the visitor journey and ask questions about the uses encouraged by the physical spaces”* (MacLeod et al., 2015, p. 330). Larson (2017) described the redesign of the exhibition galleries at the Palo Alto Art Center that leveraged design thinking as the methodology to create a solution for family engagement and interpretation.

Collaboration and service learning: Repeatedly, design thinking is a motor of collaboration between university students and local area educational organizations. Zuiker and Jordan (2019) describe a case study of design thinking to structure the collaboration of learning sciences classes and a zoo education program. Fontaine (2014) described a case study on the development of strategic thinking skills through the design of interactive museum exhibitions. In a regular class, students designed interactive exhibits for the Field Museum of Chicago. Each semester the museum’s Design Director presented a different exhibit theme, as well as the museum’s content outline, learning objectives, and relevant artifacts. Students designed several exhibits that include experiential learning components to help visitors learn about subtopics within the exhibit theme: *“As a method for emphasizing design thinking, this challenge is well suited, since it is only possible to achieve the museum’s learning objectives with a focus on user needs”* (Fontaine, 2014, p. 12). Gestwicki and McNely (2012) presented a case study on the design of an educational video game about collecting, curating, and other museum operations. During the fifteen-week seminar an interdisciplinary group of students (subject backgrounds included computer science, economics, music, history, art, psychology, theater, creative writing, animation and graphic design) employed practice-based research to design and develop an educational computer game. Leading the students through metacognitive exercises such as Sprint Retrospectives resulted in their recognizing the value and distinctiveness of the experience. The authors concluded: *“Immersive learning experiences can*

align with both academic goals and industrial settings” (Gestwicki & McNely, 2012, p. 25).

Making and Crafting in Makerspaces: Renard (2014) explored how knowledge gained through hands-on experimentation with raw material translates into better student outcomes in two consecutive courses on working with felt, that were grounded in design thinking and studio culture. The author described design thinking as intrinsically flexible and adaptable, allowing students to draw and develop their capacity to frame opportunities for change and form ideas that improve the status quo.

4.2.3 Higher Education

Design thinking in higher education beyond the studio disciplines is still predominantly applied in marketing, business or entrepreneurship education, but its application across different subject areas is growing. The literature review identified a number of case studies from varied subject matter backgrounds such as engineering, medical education, writing studies, computer science, teacher education, public administration, as well as other academic functions, such as advising and mentoring.

Business and Management: Several case studies and position papers argue that design thinking is making valuable contributions to business and management education (Dunne & Martin, 2006; Glen, Suciu, Baughn, & Anson, 2015; Koria, Graff, & Karjalainen, 2011; Matthews & Wrigley, 2017; Mumford, Zoller, & Proforta, 2016; Schlenker, 2014; Sheehan, Gujarathi, Jones, & Phillips, 2018). As Matthews and Wrigley (2017) observed, *“the numbers of higher education programs that teach design thinking to business students, managers and executives are growing”* (Matthews & Wrigley, 2017, p. 41). Glen et al. (2015) argued that it provides supplement to the analytic emphasis of business education, and benefits students who are accustomed to structured learning environments by showing them how the seemingly messy process of design thinking builds to a desired outcome. Koria et al. (2011) argued that the required culture of collaboration in the workplace is the key driver in learning design thinking, which means in practice multidisciplinary teamwork, often linked to multicultural aspects. Sheehan, Gujarathi, Jones, and Phillips (2018) described design thinking as an approach to create teaching cases for business education.

Engineering: Altringer and Habbal (2015) presented a qualitative case study of curriculum development at the School of Engineering and Applied Sciences (SEAS), where faculty successfully transitioned the curriculum towards multidisciplinary education.

Teacher Training: Anderson (2012) described how they added a design thinking cycle of emphasizing, ideating, prototyping and testing to the development of web quests in a teacher training program for enhancing project-based learning and authentic assessment. Harth and Panke (2018) applied design thinking as a conceptual framework and methodological approach for empowering the teaching agency of STEM students who are preparing for a career as vocational school teachers through a workshop on curriculum development, lesson planning and instructional techniques with engineering students. Their case study reflected the specific traits and challenges of vocational education in the German dual mode system. Based on survey results and content analysis of student papers, the authors documented central learning outcomes of the design thinking workshop: Perceiving students as individuals, perceiving oneself as a teaching professional, extending the instructional repertoire, recognizing the importance of learning environment factors such as innovative furniture, understanding threshold concepts, and experiencing the value of prototyping.

Medical Education: Gottlieb, Wagner, Wagner, and Chan (2017) discussed design thinking as complementing traditional curriculum planning approaches for medical education with the potential to *“clearly and empathetically understand the needs and problems faced by their students or trainees”* (Gottlieb et al., 2017, p. 24). While traditional needs assessments in medical education comprise approaches such as quantitative surveys of learner perceptions, this does not acknowledge the importance of the educator’s interpretation on the learners’ needs. The authors pointed to the redesign of a residency program’s academic schedule as a promising example. Badwan, Bothara, Latijnhouwers, Smithies, and Sandars (2018) illustrated the key features of design thinking in medical education by describing the activities at the #ElsevierHacks at the AMEE Conference 2017. Teams of medical students, software developers and designers engaged in design thinking with support by medical education, technical and marketing mentors to develop educational tools geared to enhancing medical education. In fall 2014, Grift and Kroeze (2016) developed a one-semester crossover course called “Hacking Healthcare” at the University of Amsterdam with the goal of fostering collaboration skills. McLaughlin et al. (2019) summarized 15 different case studies of design thinking in the public health sector (three of which involved students) and concluded that the articles analyzed converged on a set of benefits: *“All highlighted the importance and benefit of collaboration, particularly as it related to the multidisciplinary teams and the diversity of thinking that advanced the work as well as*

the identification and participation of multiple stakeholders within the process”.

Humanities: Molinari and Gasparini (2019) led a two-day workshop that centered around how to enhance student participation in university governance with students from philology programs. They started with participants writing one love letter and one break-up letter to their university. The goal of the love and break-up letters activity was to support divergent thinking and trigger empathy. The authors observed enhanced self-confidence and decisional skills among the participants.

Public Administration: Peters and Maatman (2017) discussed how a combination of foundational materials, an ill-defined problem and design thinking maximizes the students’ freedom to independently define the problem, identify the requisite information for analysis, and develop solutions.

Writing Studies: Purdy (2014) compared the design thinking and the writing process and argued that it offers a model for situating writing in the academy: *“With design thinking, processes of composing are generative, not just because these activities matter in determining what products are created, but because they shape the future and motivate the ways in which we (learn to) represent and communicate”* (Purdy, 2014, p. 626). Leverenz (2014) discussed how design thinking might help students see academic writing, as a creative act of making, *“in which writers make not only texts, but themselves and their worlds”* (Leverenz, 2014, p. 3). According to the author, writing assignments that foster design thinking should represent real design problems and allow for many possible responses that are not easy or obvious. While teachers typically have the impulse to take the wickedness out of assignments and make their expectations as explicit as possible in order to avoid confusing or frustrating students, wicked problems trigger creativity: *“As a result, we come to own the problem – as our vision – rather than merely fulfilling someone else’s idea of what should be done”* (Leverenz, 2014, p. 7). For further examples, Pope-Ruark, Moses, and Tham (2019) created an annotated bibliography that explores the role of design thinking in writing studies and technical and professional communication.

Computer Science: Valentim, Silva, and Conte (2017) argued that is important to teach design thinking in Computer Science and Software Engineering courses as an analytic and creative process because it provides a human-centered view of technological artifact design. As such, it allows instructors to better prepare students for the software development industry. The authors conducted an empirical study with 17 postgraduate students in the context of mobile applications design. Overall, students

considered design thinking valuable to their mobile application projects. Bosman (2019) conducted a class with 10 transdisciplinary technology students that deployed design thinking to generate an entrepreneurial mindset. Based on the results of pre-/post-surveys, the author observed that participants shifted their learning perspective from “weakness-focused” to “strengths-focused”.

Mentoring and Advising: The University of Wisconsin–Madison held a five-day design thinking workshop to redesign the university’s advising and registration process and provide students with a more intuitive enrollment experience, especially at orientation (Apel, Hull, Owczarek, & Singer, 2018). Parrish, Parks, and Taylor (2017) highlighted the potential of design thinking as a mentoring technique in the university’s work-study program as an opportunity to draw from the student’s and employer’s dual perspectives, enriching the knowledge of both parties: The mentor can encourage pragmatic growth and meaningful reflection as the mentee offers insight into the preferences and needs of today’s student. Utilizing the design thinking paradigm, design solutions to personal and institutional challenges can be developed together, creating authentic, interdisciplinary understanding. Similarly, Leeder (2019) described design thinking as an approach for mentoring training in sports coaching.

Interdisciplinary Programs: Holzer, Gillet, and Lanerrouza (2019) documented a design thinking class with 35 students that was held as an elective course targeted at bachelor students from different disciplinary backgrounds (computer science, engineering, architecture, mechanics, business, humanities). The authors argued that in the age of electronic learning, in particular MOOCs and other open education opportunities, it is imperative to bring students to class for a reason. Hands-on collaboration through design thinking offers such a reason. This reasoning aligns with the goals of a student-centered design thinking workshop conducted by Harth and Panke (2019), in which the participants used design thinking to develop solutions for innovative learning spaces on campus, combined with agile curricular innovation. During a two-day design thinking workshop an interdisciplinary group of 17 students produced ideas for new learning spaces and mapped out their spatial learning journeys through campus offerings and daily routines.

Perspectives of Teachers: Beligatamulla et al. (2019) conducted a qualitative interview study to discover common themes in how educators approach making sense of design thinking. They conducted three interviews with educators who have had more than fifteen years of teaching experience. Based on Interpretative

Phenomenological Analysis (IPA), the authors identified “design thinking as capability building for everyone” as an overarching theme. In addition, the study revealed four constituent themes; developing a participatory approach towards world issues; developing an open, explorative attitude; developing creative ability; and developing an ethical mindset.

Summary: This section discussed use cases and adoption patterns in K12, higher education and informal learning. The majority of design thinking literature is focused on higher education, followed by K12 and informal learning. While this is a snapshot of the scholarly discourse, it does not necessarily reflect the practice. As an example, design thinking is embedded in many maker spaces, but not necessarily the main focus of scholarly reflection on making and the Do-It-Yourself movement. Notably, the literature on design thinking in informal learning settings often blends with the higher education context through organizational collaboration and service learning.

The case studies in *informal learning settings* were situated in zoos, museums, makerspaces and libraries. They focused on four goals: (1) designing exhibits, experiences and services; (2) service learning and organizational collaboration; (3) extending exploration of artifacts, spaces and services; (4) making and crafting.

Design thinking in *formal education settings* is well documented across various disciplines and subjects. K12 and higher education share common themes connected to design thinking: (1) as an instructional design method in course material development; (2) as a curricular development technique; (3) as a teaching strategy to achieve subject-specific learning goals; (4) as a learning goal in and of itself; (5) as a facilitation technique in student support, i.e., mentoring, advising, counseling; (6) as a method for process improvement or product development; (7) as an approach for leadership and organizational development.

4.3 R3: What tools, techniques and methods characterize design thinking?

What tools, techniques and methods characterize design thinking? What activities does design thinking comprise? In answering this question, I looked specifically at case studies in the education context and extracted information on how design thinking was actualized in the specific setting. Since only about half of the case studies offer detailed information on the “how to” of design thinking, I additionally consulted references to specific formats

or techniques in theoretical scholarly literature. Lastly, I compared the review articles by Elsbach and Stigliani (2018) and Micheli et al. (2018), each of which contained a section on methods and tools.

Not unexpectedly, no clear picture of canonical methods emerged. As Dorst (2011) stated, “*many disparate, vaguely creative activities are combined under the label*”. The methods extracted varied widely in their granularity from single technique (e.g., crazy eights) to whole process (d.school process, STEM Fab Studio Design Process). In addition, design thinking methods stem from different origins and subject trajectories:

- a) Methods that have stand-alone scholarly discourses and communities of practice that are partly independent from design thinking (e.g., personas, sketchnoting, LEGO serious play, dynagrams).
- b) Methods that interface with the methodical repertoire of qualitative research in general or ethnography in particular (qualitative interviews, observation).
- c) Methods that interface with software development concepts such as rapid prototyping or early-stage end users testing (“experimentation”).
- d) Methods that were specifically developed in the context of design thinking, such as “Powers of Ten”.

Furthermore, the two overview articles that attempt classifications of design thinking tools arrive at vastly different schemes:

The systematic literature review by Micheli et al. (2018) initially identified a total of 37 tools and methods. The authors then applied card sorting exercises to organize the methods into eight main categories: Ethnographic methods, Personas, Journey map, Brainstorming, Mindmap, Visualization, Prototyping, Experiments.

Elsbach & Stigliani (2018) organize design thinking methods into three broad categories of needfinding, idea-generation and idea-testing tools:

- Needfinding tools include in-depth contextual interviews with potential users of a design solution (e.g., interviewing potential customers of a ride-sharing service), ethnography (e.g., observing and shadowing employees of a firm to develop initial requirements for a new human resource management system), or developing a holistic understanding of user experience through customer journey mapping.
- Idea-generation tools contribute to cultures of openness to ambiguity, risk taking, and collaboration (e.g., group brainstorming, customer cocreation/codesign of initial ideas)
- Idea-testing tools contribute to cultures of openness to experimentation, openness to failure, and design-

oriented strategic thinking. Idea-testing tools include rapid prototyping (i.e., developing quick and dirty models on a small scale to test ideas) and experimentation (i.e., testing some parts of a solution with actual users or internal testers).

As Watson (2015) stated: “*There are dozens of versions of the Design Process*” (Watson, 2015, p. 13). The diversified landscape of design thinking tools and frameworks is not necessarily a problem – it provides a rich menu of options, and allows to experiment and iterate, in line with fundamental tenets of design thinking. However, it also creates confusion for educators. Lor (2017) for example distinguished (incorrectly) between an advanced process applied in higher education and a simplified version prevalent in K12.

Summary: Table 1 summarizes the findings in an alphabetic overview of different design thinking processes, methods and tools that were identified in the literature review.

4.4 R4: What are the limitations of design thinking?

What are the limitations of using design thinking in education? What potential negative outcomes should educators anticipate? One of the most surprising results of this literature review is how seldom design thinking case studies report negative outcomes, failures or unintended consequences. However, it seems to go without question that design thinking cannot be a magical fix that works for anything, anyone and in any context. As von Thienen et al. (2014) described it: “*If design thinking is a means to solve problems – what problems is it good for? Obviously, it is not made to help physicists compute precise mathematical solutions*” (von Thienen et al., 2014, p. 97). Clearly, there are both limitations to the applicability of design thinking, and challenges that can lead to (partial) failure of the overall approach or specific methods. This section presents obstacles and potential problems.

Lack of Creative Confidence or Mastery: Ohly, Plückthun, and Kissel (2017) evaluated a university course that was developed based on design thinking principles. Their evaluation results revealed that although the course aimed at nurturing creative confidence, it was not effective in enhancing students’ creative self-efficacy. “*We were inspired to be creative, but in the end most ideas were not really innovative*”, as one participant commented. Valentim, Silva, and Conte (2017) conducted a qualitative observation study with 17 postgraduate students in

the context of mobile applications design. They used grounded theory coding for analyzing the data. Based on their observation data, they identified several difficulties for participants, i.e., understanding the purpose of the design thinking activities, thinking creatively, and producing project results in a fairly short time frame.

Wrong Priorities, Shallow Ideas: As Gestwicki and McNely (2012) observed “*emphasizing the perspectives of the wrong stakeholder groups can lead a team in unproductive directions*” (Gestwicki & McNely, 2012, p. 25). Glen et al. (2015) pointed out that instructors need to intervene when teams prematurely converge on a single idea: “*Students need to develop a healthy skepticism of rapid consensus, and be armed with techniques to test its veracity*” (Glen et al., 2015, p. 189).

Anxiety and Frustration: Glen et al. (2015) stated that students may experience confusion and frustration when engaging in design thinking projects for the first time, and “*even those practiced in design thinking experience periods of frustration over the course of a project*” (Glen et al., 2015, p. 189). The reason lies within the ambiguity of the process, which can turn into anxiety as the teams gather more information than they can make sense of. The authors warned that this feeling may not subside until patterns begin to emerge, and promising ideas take form as prototypes. Particularly students with a low tolerance for ambiguity may have difficulties embracing the design thinking process. Glen et al. (2015) recommended to strategically distribute such participants among teams.

Creative Over-Confidence: Taheri, Unterholzer, Hölzle, and Meinel (2016) observed that design thinking workshops can lead to creative over-confidence. The lack of critical feedback regarding the skills participants demonstrate, especially in short workshop settings with focus on productive outcomes and learning experience, results in a rather slow development of skill-based learning, especially for those who have no prior expertise (e.g., no prior experience with user research: “*Neglecting the skill-based outcomes may lead to educating individuals with creative over-confidence, who lack the skills and knowledge to apply their creativity*” (Taheri et al., 2016, p. 10).

Teamwork Conflicts: The interaction between the participants inside the team can influence the implementation of design thinking (Valentim, Silva, & Conte, 2017). Goldman et al. (2014) conducted a systematic investigation of team dynamics in design thinking student teams. The researchers followed two teams, from two courses, as they met outside of class to work on their class-assigned projects. The authors stated: “*Conflicts among group members seem endemic in teamwork and surfaced*

Table 1: Design Thinking Tools, Alphabetic Overview.

A/B/C idea sorting	A (ready-to-start) ideas, B (mid-term) ideas, and C (long-term) ideas.
Actor Map	visualization of key stakeholders,
Affinity mapping	organizing related observations, facts, or aspects into distinct clusters.
Analogous Empathy	allows participants to understand a specific experience based on familiar experiences that offer analogies.
BoF (“Birds of a feather”)	conference format based on the saying “Birds of a feather flock together”, that can be used in workshops for gathering spontaneously around topics of interest to form groups.
Bodystorming	asks participants to immerse themselves in the physical space where a new product or service will be used and role play the interactions that take place.
Cards (“Method Kit”)	allow to combine people, scenes, settings, tools, etc. in form of cards.
Card sorting	works by presenting participants with a set of pre-made cards and asking them to prioritize or organize them into groups.
Co-Creation Workshop	structured participation opportunity for different stakeholders in the design process, because meeting with stakeholders spurs empathy-building (Gestwicki & McNely, 2012).
Crazy eights	fast-paced sketches (typically less than five minutes) of ideas and interfaces, that work with a single sheet of paper that is folded three times to create eight panels. Each panel holds a sketch or note.
Design thinking process elementary	model for using design thinking with elementary school students developed by Lee, Yoon, and Kang (2015).
d.school process	formalized sequence of design thinking activities. Stanford d.school created an open educational resource that offers a replicable and widely used stage-structured and step-by-step process. The steps consist of (a) empathize, (b) define or point of view, (c) ideate, (d) prototype, and (e) test.
Dynagrams	graphic deliberation tools. Eppler and Kernbach (2016) distinguish three specific kinds of dynagrams: (1) Roper dynagram (to better understand client preferences), (2) Sankey dynagram (to match needs and solution features) and (3) Confluence dynagram (to explore and design prototype features).
Empathy maps	template that consists of four quadrants that allow participants to group items from observations and interviews around things the subjects: Said, Did, Thought, and Felt (Valentim, Silva, & Conte, 2017).
Ethnography	immersive, qualitative methodology that informs design thinking through field notes, photographs, videos and artifacts that support empathy with stakeholder groups.
Fablab	location for prototyping phase of design thinking.
Flexible furniture	rooms equipped with flexible furniture are described as important for ideating phase across several publications.
Focus Group	qualitative research method, also prominent in UI/UX.
Frames	alternative viewpoints or perceptions that allow designers to approach a problem or situation for value creation.
graasp.eu	social learning platform, used for documentation.
“How might we” (HMW)	short questions that launch brainstorming.
Hummingbird	robotic controller and visual programming language developed by Carnegie Mellon University’s Community Robotics, Education and Technology Empowerment Lab (CREATE Lab). Each robot kit includes a set of motors, LEDs, sensors, and electronics for building and programming.
IDEO Method Cards	card set for design processes.
Interviews	qualitative research method, used often in form of one or two open-ended questions, inform the empathy stage, and are an example of the appropriation of qualitative methods in design thinking.
Journey Maps	visualizations of the steps that a person undergoes in order to accomplish a goal. It can be a timeline, spatial map or narrative, and typically includes touch points.

Continued **Table 1:** Design Thinking Tools, Alphabetic Overview.

LEGO bricks	often part of the equipment of innovation spaces and labs in which design thinking takes place. Their main use is for prototyping or scenario building, or as part of LEGO Serious Play activities.
LEGO Duplo bricks	can be used by groups to collaboratively build structures, in which the bricks or plates represent physical or digital objects (e.g., menu items), chronological units (time segments) or pedagogical settings (e.g., dyads, groups, lectures). Panke et al. (2014) and Panke (2016) described the use of LEGO Duplo bricks to develop website sitemaps and homepage elements, as well as to design instructional activities.
LEGO Serious Play (LSP)	facilitation methodology created by LEGO. Since 2010 the methodology is available under an open source community-based model that offers a creative commons licensed handbook (“LEGO SERIOUS PLAY Open Source Document”). It is a scripted and formalized process for using Lego bricks and figures for strategic decision making and organizational development. http://seriousplaypro.com/about/open-source/
Love / break-up letters	writing prompts to get feedback on the organization, i.e. the education institution.
Marshmallow-Challenge	team building exercise that involves building the tallest freestanding tower using dry spaghetti, a yard of tape, a yard of string and a marshmallow that has to be balanced on top.
Mindmaps	diagram that organizes hierarchical information, grouping categories around a central topic.
miro.com	web-based visual collaboration tool, used for a start-stop-continue exercise.
Ninety-second critiques	concise form of feedback on initial ideas or prototypes.
Observation	systematic inspection of an event to better understand a situated practice.
padlet.com	web-based visual collaboration tool, used for agile curricular planning.
Personas	technique for bringing abstract target group information to life through the presence of a specific, fictional personality. Personas aid in identifying needs and possible behavioral patterns and are typically generated based on either demographic information or interview data.
Point of View (POV) madlib	used for reframing a design challenge into an actionable problem statement. The madlib captures and harmonizes three elements of a POV: user, need, and insight. [USER] needs to [USER’S NEED] because [SURPRISING INSIGHT].
Possibility Space	sequence of divergence-convergence steps that alternately expand and reduce variation, model developed by Thoring and Müller (2011).
Powers of Ten	reframing technique that encourages participants to take a step back and look at the problem from a broader context, or to take a step closer and look at it in more detail. The name stems from two short American documentary films written and directed by Charles and Ray Eames. The films first expands out from the Earth until the entire universe is surveyed, then zooms in until a single atom and its quarks are observed.
Prototyping	essential design thinking methods that plays a role in most if not all formats: “ <i>All design thinking literature involves the term prototyping</i> ” (Camacho, 2018, p. 636). In design thinking, prototyping is a constant and simultaneous interplay between learning and creating, that involves conceptualizing, building, testing and evaluating (Camacho, 2018). Initial prototypes roughly represent ideas, using material such as paper and tape, clay or Play-Doh, LEGOs, cardboard, wood and various other, often recycled material.
Role play	assigns scripted roles to participants and allows to test out positions, arguments and experiences in a playful setting.
Scratch	free, visual programming language and online environment where learners can create interactive stories, games, and animations.
Sketchnoting	refers to taking notes enhanced with sketches, doodles, or simple drawings as well as text. The methodology that uses simple shapes, frames, and connectors to visualize complex information, concepts, and physical objects.
Stanford Model	design thinking method kit, developed for K12 education.
STEM Fab Studio Design Process	developed by Nick DiGiorgio for FabLab and the Cleveland City Public Schools in 2012 (cf. Watson, 2015). The steps of this process are Ask, Imagine, Design, Build, Evaluate, Refine, and Share.
Storyboard	sequence of illustrations to visualize activities or interactions.

Continued **Table 1:** Design Thinking Tools, Alphabetic Overview.

Touch Points	locations where people interact with an organization or service. Mapping these touch points in form of visualizations or models, or integrating them into personas allows to identify effective ways of changing interactions between individuals, groups and organization (see “customer journey maps”).
Yarn Network	networking technique in which participants form a circle and throw a ball of yarn to someone in the circle whilst holding onto the string, based on appreciation, shared backgrounds or other prompts. The process is repeated until all members have at least one connection (cf. Harth & Panke, 2018).
Visual storytelling	storyboarding activities that ask participants to use a sketch or series of sketches to tell a story.
What’s on your plate	exercise that uses a paper plate to offer participants a vehicle for sharing problems. They are encouraged to note or draw “What’s on your plate right now”.

in this study” (Goldman et al. 2014, p. 13). One team in particular established uneven participation patterns and those patterns resulted in noticeable tensions. The authors concluded that it is important to pay attention to teams’ abilities to recognize ambiguity in the design process. Similarly, Aflatoony, Wakkary, and Neustaedter, (2018) observed that conflicts around teamwork stemmed from lack of group leadership, problems with sharing tasks equally and the size of the teams.

Sprint instead of long-term focus: Grots and Creuznacher (2016) cautioned that design thinking is not able to cover the span from the need for change to final implementation of results: “*Design Thinkers usually lack the patience for detailed implementation of solutions*” (Grots & Creuznacher, 2016, p. 192). Instead, the authors argue that design thinking is most suitable for discovering different options, finding reasons for a decision, and establishing priorities. The method lacks elements for turning ideas into accepted solution: “*This is where the individual disciplines come in (among them: designers, organizational experts, HR professionals), with the knowledge and skills to fill a new idea with life and to implement it in a company*” (Grots & Creuznacher, 2016, p. 192). Similarly, Panke and Harth (2018) observed that it was unclear for participants in a design thinking workshop on inclusive community development how to move from the ideas generated in the design thinking process to the development of innovative, marketable products and services.

Idea creation over evaluation: Panke and Harth (2018) observed that particularly in a short workshop format there is not enough time to fully investigate and explore ideas. The case study evaluated a one-day format, and noted that it lacked the opportunity to research whether the imagined solutions already existed, and whether they made sense. Some participants struggled with the openness and complained that all comments and ideas were treated equally, and that there were not enough opportunities for evidence-based evaluation of proposals.

Tensions between learning content and design thinking process: As Carroll et al. (2010) pointed out, creating a classroom project that aligns academic standards, curricular content and design thinking is a difficult endeavor. In their geography case study, the researchers noted that students’ responses to what they learned about geography demonstrated a lack of connection between subject and method: “*Geography? Nothing really. Geography? That’s the study of the earth, right?... mmm. I don’t know. Geography? I forgot. I didn’t really learn that much*” (Carroll et al., 2010, p. 50).

Summary: Despite the apparent benefits of design thinking, many open questions and potential tensions remain that warrant caution from educators. While few case studies reported on negative outcomes, the literature review yielded a substantial list of potential problems: Lack of creative confidence, teamwork conflicts, anxiety and frustration, shallow ideas, idea creation over evaluation, lack of long-term impact, overconfidence, misalignment between learning content and design thinking process. Similarly to the positive outcomes, it is unlikely that any design thinking experience will show all or even several of these problems. Instead, the themes offer facilitators potential issues to watch out for, and, in terms of case study evaluation, can translate into balanced post-workshop surveys.

5 Discussion

When design thinking first gained popularity in context that expanded beyond the traditional preoccupations of designers through the seminal publications by Tim Brown (2009) and Roger Martin (2009) the considerable attention quickly became a double-edged sword: Kimbell (2011) described design thinking as undertheorized and understudied: “*Even on a cursory inspection, just what design thinking is supposed to be is not well understood,*

either by the public or those who claim to practice it" (Kimbell, 2011, p. 289).

In the meantime, essential attributes, applications and outcomes of design thinking have, to a degree, solidified. Recent publications in form of literature reviews and edited volumes clearly document advances in the theoretical discourse and empirical descriptions. This article is part of the ongoing endeavor to clarify the nature of design thinking and allow practitioners and researchers alike to advance its theoretical foundation, empirical reflection, and practical implementation. This review expanded and updated the corpus of Lor (2017) and complemented the thorough foundational work on design thinking in business and management by Micheli et al. (2018) with an educational system focus. It provides both a robust dataset with a large corpus of design thinking literature and analytical codes for future research, re-analysis and further interpretation. Leveraging Zotero as a free and open source reference management software allows for sharing the corpus in an open format. The bibliographic dataset is available in the UNC Dataverse (<https://dataverse.unc.edu/dataverse/panke>).

The authors von Thienen, Royalty, and Meinel (2017) describe design thinking for education as a problem-based learning paradigm that builds on three pillars: A creative problem solving process, creative work-spaces and collaboration in multi-perspective teams. We found these three key ingredients across multiple educational contexts and settings. Seven different categories for the application of design thinking in education emerged in the literature review: (1) design thinking as an instructional design method for the development of course content or teaching material (e.g., Sheehan et al., 2018); (2) design thinking in curricular development (e.g., Altringer & Habbal, 2015); (3) design thinking as a teaching strategy to achieve subject-specific learning goals; (4) design thinking process and mindset as a learning goal in and of itself; (5) design thinking in student support, i.e., mentoring, advising, counseling; (6) design thinking for process improvement or product development; (7) design thinking for leadership and organizational development.

Practitioners will find the tools and techniques section particularly fruitful in charting their own design thinking journey. I purposefully chose a different classification of tools than Micheli et al. (2018), because I wanted to provide a more granular account of the diversity of design thinking practices. An expert survey among educators who use design thinking presents itself as an ideal follow-up project that can provide clarity and generate systematic descriptions of different design thinking exercises and their applicability for specific purposes. The systematic

organization should include digital prototyping tools such as visual programming languages, and physical engineering tools, that are typically found in makerspaces.

Getting a better handle on what it is that people actually *do*, when they engage in design thinking activities deserves further research. This is particularly interesting in light of the findings by Primus and Sonnenburg (2018), that stated that while overall design thinking creates flow on the individual and group level, the flow experience may differ between sets of exercises. More case studies should report the details of their "design thinking design" to allow for best practices to emerge. This includes a description of the spaces and places of design thinking to explore the role of innovative furniture and flexible learning spaces.

The article covers novel ground in seeking to shed light on the limitations of design thinking. While there are plenty of critics that see design thinking as a fad (cf. Hernández-Ramírez, 2018), more articles that include nuanced weighing of costs and benefits, intended and unintended outcomes, affordances and limitations will be necessary for enhancing design thinking practices as well as scholarly reflections among its proponents.

From a theoretical perspective, the article builds bridges between design thinking and related innovative pedagogies. Von Thienen, Clancey, Corazza, and Meinel (2017) pointed out that investigations into the history of design thinking hold the promise of adding systematically to our comprehension of its basic principles. According to Leifer and Meinel (2016), it is the combination of engineering (especially IT), economics, anthropology, psychology, neuroscience and design-research that makes design thinking foundational. Similarly, this articles stresses that we cannot understand design thinking in isolation from related disciplines with intersecting scholarly communities and core concepts, in particular participatory design, bricolage/tinkering, serious play and making. Future work that focuses on the intersections of, for example, design thinking and making or design thinking and participatory design are promising avenues to gaining renewed inspiration and opening up additional educational opportunities.

The themes we identified as meaningful in the educational context differ from previous work in business and organizational development. At the same time, there are notably a number of similar elements. On the one hand, design thinking is not context-neutral, on the other hand, there are significant overlaps between design thinking in education, business, and policy innovation. Powerful themes can emerge across domains. What sets design thinking in education apart from other contexts is the interplay between

innovation approach and curriculum. While design thinking can be taught as a standalone subject, its appeal in an educational context stems from being a conduit for academic learning goals. As Carroll et al. (2010) stated: “*Design thinking must be integrated into academic content. While it may stand alone, its power as a tool for learning comes in the ways it can support a diverse range of interdisciplinary academic content*” (Carroll et al., 2010, p. 51).

This is not to say that design thinking should be taught in academic silos. As demonstrated by the success of Stanford d.school and Potsdam Hasso Plattner Institute, there is potential for multidisciplinary design thinking programs in education. With their model of the “educational design ladder” Wrigley and Straker (2017) developed a transferable concept that provides a process for the organization and structuring of units for a multidisciplinary curriculum.

6 Conclusion

Design thinking is both a process and mindset that evolved from research on “designerly thinking” into a problem solving approach primarily adopted in business, to a widespread way of addressing wicked problems that plays a growing role in education. It has roots in and interconnections to participatory design, serious play, bricolage, tinkering and making, sharing both tools and techniques as well as characteristic traits and outcomes. With the growing adoption of design thinking, its practice is becoming more diversified, but, in turn, our understanding of its merits and limitations are becoming more pronounced due to an extensive body of scholarly work.

Motivations for using design thinking in education are typically multifaceted: Educators are hoping for surprising ideas, elegant solutions and novel concepts, they want to facilitate a learning or development event in a new and invigorating format, and induce transferable skills and competencies among the participants. What will learners gain as a result of taking part in a design thinking event? What do instructors need to know before considering the approach? One answer to these questions is a quote by a middle school student in a classroom experiment on design thinking described by Carroll et al. (2010): “*It’s cool, it’s fun, and it takes a lot of time*” (Carroll et al., 2010, p. 48).

Across case studies, a shared, positive narrative emerges: Taking part in design thinking activities can be a transformative experience of amazement, camaraderie and joyful discovery. We documented characteristics that

are particularly meaningful in a pedagogical setting: Tacit experiences, increased empathy, reduced cognitive bias, playful learning, flow, verve, inter/meta-disciplinary collaboration, productive failure, resilience, surprising solutions and creative confidence.

At the same time, the literature suggests that educators should consider the limitations of design thinking, be perceptive of potential problems during workshops, evaluate results and experiences, and adjust their design thinking practices flexibly. Tensions between learning content and design thinking process, a lack of long-term focus, and insufficient time to fully and critically evaluate ideas are general limitations of the approach. Other potential problems that can arise are a lack of creative confidence or mastery, experiences of anxiety and frustration, teamwork conflicts, wrong priorities, shallow ideas and creative over-confidence.

Research on design thinking needs to move past the trope of “what is design thinking?”, and instead transfer attention to more specific questions that will inform the “design of design thinking”. Being immersed in the literature of design thinking has led me to the following immanent implications for research and practice:

- **Fail fast (and often):** More design thinking case studies should entail descriptions of failure. What did not go well? How can facilitators or instructors can turn things around? How can we iterate and improve?
- **Learn across case studies:** Shared survey question banks or model questionnaires could promote evaluations that measures effectiveness of design thinking in three areas: (a) experiences during process, (b) product outcomes, and (c) mindset changes.
- **Learn from related fields:** Researchers and practitioners should explore theoretical and practical interconnections between design thinking and related communities.
- **Design and Redesign:** Design thinking facilitators deploy a large variety of methods, models, techniques and tools. A systematic handbook on design thinking methods and tools could help educators leverage the approach to its fullest potential³.
- **Play the long game:** There is a gap in our understanding of mid- or long-term effects. More case studies should follow up after design thinking formats to track changes in mindset, and document the trajectories of ideas.

³ Stanford d.school currently offers a variety of creative commons material in wiki format: <https://dschool-old.stanford.edu/groups/k12/>

Table 2: Overview of results and key takeaways.

Research Question	Results	Key Takeaways
Potential: What is the potential of design thinking for education?	Nine themes emerged from design thinking literature: Tacit experiences, increased empathy, reduced cognitive bias, playful learning, flow/verve, collaboration, productive failure/resilience, surprising solutions, creative confidence.	Themes for describing the goals and evaluating the outcomes of design thinking
Settings: How is design thinking applied in different educational settings (K12, informal learning, higher education)?	Informal settings: (1) designing exhibits, experiences and services; (2) service learning and organizational collaboration; (3) extending exploration of artifacts, spaces and services; (4) making and crafting. Formal settings (K12 / higher education): (1) as an instructional design method in course material development; (2) as a curricular development technique; (3) as a teaching strategy to achieve subject-specific learning goals; (4) as a learning goal in and of itself; (5) as a facilitation technique in student support, i.e., mentoring, advising, counseling; (6) as a method for process improvement or product development; (7) as an approach for leadership and organizational development.	Schematic overview for contextualizing new case studies; corpus for further analysis
Tools: What tools, techniques and methods characterize design thinking?	Review yielded 50 different tools, models, techniques, methods. Granularity varied from single technique (e.g., crazy eights) to whole process (d.school process, STEM Fab Studio Design Process). Various origins and subject trajectories.	Planning help for design thinking facilitators; corpus material for further analysis
Limitations: What are the limitations of design thinking?	Review identified eight potential negative outcomes: Lack of creative confidence, teamwork conflicts, anxiety and frustration, shallow ideas, idea creation over evaluation, lack of long-term impact, overconfidence, misalignment between learning content and design thinking process.	Themes for evaluating the outcomes of design thinking, decision-making help for educators

This article is an attempt to chart a map across the complex and fascinating landscape of design thinking practices in education. Table 2 depicts a summary of the results.

Design thinking is a versatile approach for orchestrating conflicting ideas, identifying singular needs and common goals, making productive use of diverse backgrounds, enhancing empathy, and developing a shared vision. While the situated practices of design thinking are diverse, we identified characteristic themes that explain why design thinking is heralded as a problem-solving approach in education and beyond.

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