# Design thinking

**Design thinking** refers to design-specific cognitive activities that designers apply during the process of designing.[1]

## 1 Origins of the term

For more details on the history of the term, see § History.

The notion of design as a "way of thinking" in the sciences can be traced to Herbert A. Simon's 1969 book *The Sciences of the Artificial*,[2] and in design engineering to Robert McKim's 1973 book *Experiences in Visual Thinking*.[3] Peter Rowe's 1987 book *Design Thinking*, which described methods and approaches used by architects and urban planners, was a significant early usage of the term in the design research literature.[4] Rolf Faste expanded on McKim's work at Stanford University in the 1980s and 1990s,[5][6] teaching "design thinking as a method of creative action."[7] Design thinking was adapted for business purposes by Faste's Stanford colleague David M. Kelley, who founded IDEO in 1991.[8] Richard Buchanan's 1992 article "Wicked Problems in Design Thinking" expressed a broader view of design thinking as addressing intractable human concerns through design.[9]


*Design thinking example video*

## 2 Solution-based thinking

Design thinking is a formal method for practical, creative resolution of problems and creation of solutions, with the intent of an improved future result. In this regard it is a form of solution-based, or solution-focused thinking – starting with a goal (a better future situation) instead of solving a specific problem. By considering both present and future conditions and parameters of the problem, alternative solutions may be explored simultaneously. Nigel Cross asserted that this type of thinking most often happens in the built, or artificial, environment (as in artifacts).[10]

This approach differs from the analytical scientific method, which begins with thoroughly defining all the parameters of the problem in order to create a solution. Design thinking identifies and investigates with both known and ambiguous aspects of the current situation in order to discover hidden parameters and open alternative paths which may lead to the goal. Because design thinking is iterative, intermediate "solutions" are also potential starting points of alternative paths, including redefining of the initial problem.

### 2.1 Bryan Lawson – architects vs. scientists

In 1972 psychologist, architect and design researcher Bryan Lawson conducted an empirical study to investigate the difference between problem-focused solvers and solution-focused solvers. He took two groups of students – final year students in architecture and post-graduate science students – and asked them to create one-layer structures from a set of colored blocks. The perimeter of the structure had to optimize either the red or the blue color; however, there were unspecified rules governing the placement and relationship of some of the blocks. Lawson found that:

> The scientists adopted a technique of trying out a series of designs which used as many different blocks and combinations of blocks as possible as quickly as possible. Thus they tried to maximise the information available to them about the allowed combinations. If they could discover the rule governing which combinations of blocks were allowed they could then search for an arrangement which would optimise the required colour around the layout. *[problem-focused]* By contrast, the architects selected their blocks in order to achieve the appropriately coloured perimeter. If this proved not to be an acceptable combination, then the next most favourably coloured block combination would be substituted and so on until an acceptable solution was discovered. *[solution-focused]*

*— Bryan Lawson, How Designers Think*[11]

Nigel Cross concluded that Lawson's studies suggested that scientists problem solve by analysis, while designers problem solve by synthesis.[10] Kelley and Brown argue that design thinking uses both analysis and synthesis.

### 2.2 Analysis and synthesis

The terms analysis and synthesis come from (classical) Greek and mean literally "to loosen up" and "to put together" respectively. In general, analysis is defined as the procedure by which we break down an intellectual or substantial whole into parts or components. Synthesis is defined as the opposite procedure: to combine separate elements or components in order to form a coherent whole. However, analysis and synthesis, as scientific methods, always go hand in hand; they complement one another. Every synthesis is built upon the results of a preceding analysis, and every analysis requires a subsequent synthesis in order to verify and correct its results.[12]

### 2.3 Divergent thinking versus convergent thinking

Design thinking employs divergent thinking as a way to ensure that many possible solutions are explored in the first instance, and then convergent thinking as a way to narrow these down to a final solution. Divergent thinking is the ability to offer different, unique or variant ideas adherent to one theme while convergent thinking is the ability to find the "correct" solution to the given problem. Design thinking encourages divergent thinking to ideate many solutions (possible or impossible) and then uses convergent thinking to prefer and realize the best resolution.

## 3 Design thinking as a process for problem-solving

Unlike analytical thinking, design thinking is a process which includes the "building up" of ideas, with few, or no, limits on breadth during a "brainstorming" phase.[13] This helps reduce fear of failure in the participant(s) and encourages input and participation from a wide variety of sources in the ideation phases. The phrase "thinking outside the box" has been coined to describe one goal of the brainstorming phase and is encouraged, since this can aid in the discovery of hidden elements and ambiguities in the situation and discovering potentially faulty assumptions.

One version of the design thinking process has seven stages: *define, research, ideate, prototype, choose, implement*, and *learn*.[2] Within these seven steps, problems can be framed, the right questions can be asked, more ideas can be created, and the best answers can be chosen. The steps aren't linear; can occur simultaneously and be repeated. A simpler expression of the process is Robert McKim's phrase "Express–Test–Cycle".[3] An alternative five-phase description of the process is described by Christoph Meinel and Larry Leifer: *(re)defining the problem, needfinding and benchmarking, ideating, building, testing*.[14] Yet another way to look at it is Shewart's PDSA cycle.

Although design is always influenced by individual preferences, the design thinking method shares a common set of traits, mainly: creativity, ambidextrous thinking, teamwork, user-centeredness (empathy), curiosity and optimism.[6]

The path through these process steps is not strictly circular. Meinel and Leifer state: "While the stages are simple enough, the adaptive expertise required to choose the right inflection points and appropriate next stage is a high order intellectual activity that requires practice and is learnable."[14]

## 4 Attributes of design thinking

### 4.1 Principles

Christoph Meinel and Larry Leifer assert that there are four principles to design thinking:[14]

- The human rule – all design activity is ultimately social in nature
- The ambiguity rule – design thinkers must preserve ambiguity
- The re-design rule – all design is re-design
- The tangibility rule – making ideas tangible always facilitates communication

### 4.2 Wicked problems

Design thinking is especially useful when addressing what Horst Rittel referred to as *wicked problems*, which are ill-defined or tricky (as opposed to wicked in the sense of malicious).[15] With ill-defined problems, both the problem and the solution are unknown at the outset of the problem-solving exercise. This is as opposed to "tame" or "well-defined" problems where the problem is clear, and the solution is available through some technical knowledge.[16]

For wicked problems, the general thrust of the problem may be clear, however considerable time and effort is spent in order to clarify the requirements. A large part

of the problem solving activity, then, consists of problem definition and problem shaping.[17]

### 4.3 The "a-ha moment"

The "a-ha moment" is the moment where there is suddenly a clear forward path.[18] It is the point in the cycle where synthesis and divergent thinking, analysis and convergent thinking, and the nature of the problem all come together and an appropriate resolution has been captured. Prior to this point, the process may seem nebulous, hazy and inexact. At this point, the path forward is so obvious that in retrospect it seems odd that it took so long to recognize it. After this point, the focus becomes more and more clear as the final product is constructed.[19]

### 4.4 Methods and process

*Design methods* and *design process* are often used interchangeably, but there are significant differences between the two.

Design methods are techniques, rules, or ways of doing things which are employed within a design discipline. The methods for design thinking include interviewing, creating user profiles, looking at other existing solutions, creating prototypes, mind mapping, asking questions like the five whys and situational analysis.

Because of design thinking's parallel nature, there are many different paths through the phases. This is part of the reason design thinking may seem to be "fuzzy" or "ambiguous" when compared to more analytical, Cartesian methods of science and engineering.

Some early design processes stemmed from soft systems methodology in the 1960s. Koberg and Bagnall wrote *The All New Universal Traveller* in 1972 and presented a circular, seven-step process to problem-solving. These seven steps could be done lineally or in feed-back loops.[20] Stanford's d.school developed an updated seven step process in 2007.[21] Other expressions of design processes have been proposed, including a three-step simplified triangular process (or the six-part, less simplified pyramid) by Bryan Lawson.[11] Hugh Dubberly's free e-book *How Do You Design: A Compendium of Models* summarizes a large number of design process models.[22]

Design thinking calls for considering the given user case from various perspectives, empathizing with users, and addressing various stakeholders.

### 4.5 The use of visual analogy in design thinking and learning

Ill-defined problems often contain higher-order and obscure relationships. Design thinking can address these through the use of analogies. An understanding of the expected results, or lack of domain-related knowledge for the task, may be developed by correlating different internal representations, such as images, to develop an understanding of the obscure or ill-defined elements of the situation. The process involves several complex cognitive mechanisms, as the design task often has elements in multiple cognitive domains—visual, mathematical, auditory or tactile—requiring the usage of multiple "languages", like visual thinking.

## 5 Differences from science and humanities

Although many design fields have been categorized as lying between Science and the Arts and Humanities, design may be seen as its own distinct way of understanding the world, based on solution-based problem solving, problem shaping, synthesis, and appropriateness in the built environment.

One of the first design science theorists, John Chris Jones, postulated that design was different than the arts, sciences and mathematics in the 1970s. In response to the question "Is designing an art, a science or a form of mathematics?" Jones responded:

> The main point of difference is that of *timing*. Both artists and scientists operate on the physical world as it exists in the *present* (whether it is real or symbolic), while mathematicians operate on abstract relationships that are independent of historical *time*. Designers, on the other hand, are forever bound to treat as real that which exists only in an imagined *future* and have to specify ways in which the *foreseen* thing can be made to exist.
> — *John Chris Jones, Design Method*[23]

Design can be seen as its own culture in education, with its own methods and ways of thinking which can be systematically taught in both K-12 and higher education. Nigel Cross set out to show the differences between the humanities, the sciences, and design in his paper "Designerly Ways of Knowing". He observed that:[10]

> *The phenomenon of study in each culture is*
>
> - in the sciences: the natural world
> - in the humanities: human experience
> - in design: the artificial world
>
> *The appropriate methods in each culture are*

- in the sciences: controlled experiment, classification, analysis
- in the humanities: analogy, metaphor, evaluation
- in design: modeling, pattern-forming, synthesis

*The values of each culture are*

- in the sciences: objectivity, rationality, neutrality, and a concern for "truth"
- in the humanities: subjectivity, imagination, commitment, and a concern for "justice"
- in design: practicality, ingenuity, empathy , and a concern for "appropriateness"

## 5.1 The languages of design

Conventionally, designers communicate mostly in visual or object languages.[10][24] Gänshirt as well as Krazny have shown that even though most designers might use drawings, scale models, or prototypes as their primary means of design, in practice an unlimited range of visual and verbal design tools is being used for design thinking.[25][26] Symbols, signs, and metaphors are used through the medium of sketching, diagrams and technical drawings to translate abstract requirements into concrete objects. The way designers communicate, then, is through understanding this way of coding design requirements in order to produce built products.[27]

## 5.2 Design thinking in business

Design thinking has two common interpretations in the business world:

1. Designers bringing their methods into business by either taking part themselves in business process, or training business people to use design methods
2. Designers achieving innovative outputs or products (for example, the iPod)

The first interpretation has been described by Tim Brown, CEO of IDEO, at a TED lecture,[28] though his blog[29] also considers the second interpretation.

The limits of the first kind of design thinking in business are also being explored. Not all problems yield to design thinking alone, where it may be a "temporary fix".[30] Design thinking companies including IDEO and Sense Worldwide are responding to this by building business thinking capabilities.[31]

Tim Brown has argued that design thinking is now widely, but sporadically, used in business. He argues that competitive advantage comes from sustained use of design thinking, from becoming "masters of the art."[32]

In organization and management theory, design thinking forms part of the Architecture/Design/Anthropology (A/D/A) paradigm, which characterizes innovative, human-centered enterprises. This paradigm also focuses on a collaborative and iterative style of work and an abductive mode of thinking, compared to practices associated with the more traditional Mathematics/Economics/Psychology (M/E/P) management paradigm.[33]

## 5.3 Design thinking in education

Design thinking has been suggested for use in schools in a variety of curricular ways,[34][35][36] as well as for redesigning student spaces and school systems.[37]

Design thinking in education typically takes three forms: helping school administrators solve institution-based problems, aiding educators develop more creative lesson plans, and engendering design thinking skills in students.

There are currently many researchers exploring the intersection of design thinking and education.[38] The REDLab group, from Stanford University's Graduate School of Education, conducts research into design thinking in K-12, secondary, and post-secondary settings.[39] The Hasso Plattner Design Thinking Research Program is a collaborative program between Stanford University and the Hasso Plattner Institute from Potsdam, Germany.[38][40] The Hasso Plattner Design Thinking Research Program's mission is to "apply rigorous academic methods to understand how and why design thinking innovation works and fails."[40]

In addition to enriching curriculum and expanding student perspectives, design thinking can also benefit educators. Researchers have proposed that design thinking can enable educators to integrate technology into the classroom.[41]

Design thinking as a viable curricular and systemic reform program is increasingly being recognized by educators. "Much of today's education system guides students toward finding the correct answers to fill-in-the blanks on standardized tests, as this kind of instruction facilitates streamlined assessments to measure success or failure... It is critical that, particularly in under-served schools this model of learning does not continue to prevail. Students need both the skills and the tools to participate in a society where problems are increasingly complex and nuanced understandings are vital."[42]

### Uses in K-12 education

In the K-12 arena, design thinking is employed to promote creative thinking, teamwork, and student respon-

sibility for learning. The non profit Tools at Schools aims to expose students, educators, and schools to design thinking. The organization does this by facilitating a relationship between a school and a manufacturing company. Over a minimum of six months, representatives from the manufacturing company teach students the principles of design and establish the kind of product to be designed.[43] The students collaborate to design a prototype which is created by the manufacturer.[43] Once the prototype arrives, the students must promote the product and support the ideas that lead to its design.[43]

An example of the Tools at Schools partnership is the redesign of school equipment by 8th grade students at The School at Columbia University. The students were divided into groups and asked to redesign a locker, chair, or a desk to better suit the needs of 21st century pupils.[44] The students' final products were displayed at the International Contemporary Furniture Fair where they demonstrated their product to fair attendees and industry professionals.[44] Overall Tools at Schools not only introduces students to the design process, it exposes them to the design profession through their interactions with designers and manufacturers.[44] Since the students work together in groups, design thinking in education also encourages collaborative learning.

Another organization that works with integrating design thinking for students is the corporation NoTosh. NoTosh has a Design Thinking School to teach instructors how to implement design thinking into their curriculum. One of the design thinking techniques NoTosh adopted from the corporate world and applied to education is hexagonal thinking. Hexagonal thinking consists of gathering cut-outs in hexagon shapes and writing a concept or fact on each one. Students then connect the hexagons by laying related ideas or facts together. The visual representation of relationships helps students better conceptualize wicked problems.[45] Another concrete example of design thinking in action is NoTosh's "Googleable vs NonGoogleable Questions" exercise.[45] Given a specific topic, students brainstorm questions on that issue and divide their questions into "Googleable and NonGoogleable."[45] Students research the Googleable questions and present their findings to the class while the NonGoogleable questions are used to create a project.[45]

### Stanford University's Taking Design Thinking to Schools Initiative

Apart from non profit entities and corporations, research universities are also involved in deploying design thinking curriculum to K-12 schools. Part of Stanford University's efforts to incorporate design thinking in education into a hands-on setting is the Taking Design Thinking to Schools initiative. The Stanford School of Education and d.school partner with K-12 teachers in the Palo Alto area to discover ways to apply design thinking in an educational setting.[46] "Teachers and students engage in hands-on design challenges that focus on developing empathy, promoting a bias towards action, encouraging ideation, developing metacognitive awareness and fostering active problem solving."[46]

Taking Design Thinking to Schools identifies the following design thinking process:

- *Understand*: students explore the topic through research and develop familiarity with the subject matter
- *Observe*: this phase consists of students taking note of their environment which includes physical surroundings and human interactions; students gather more information about peoples' actions and possible motivation through discussion
- *Point of view*: students consider alternate points of views to better understand the problem and to inform their ideas in the next phase
- *Ideate*: this phase consists of students brainstorming ideas without criticism or inhibition. In this phase, the focus is on generating lots of ideas with an emphasis on creativity and enjoying the process.
- *Prototype*: in this phase students create quick prototypes to investigate ideas generated during the ideation phase
- *Test*: students test their ideas in a repetitive fashion and determine which aspects of the design are effective and which could be improved.[46]

By employing this process, the Stanford team and Taking Design Thinking to Schools participants collaborate to develop coursework that students will find engrossing and "hands-on."[46] Thus, the program at Stanford combines both design thinking for teachers who must create alternative curriculum and students who must complete the design thinking-based projects.

### The K12 Lab at Stanford

The K12 Lab network is a part of the Stanford University d.school and according to its website its mission is to "inspire and develop the creative confidence of educators and support edu innovators catalyzing new models for teaching and learning."[47] The K12 Lab Network publishes a wiki with information on creating design challenges for K-12 schools. The wiki provides tools for thinking about design challenges as well as criteria for implementing design challenges.[48]

### The Design Thinking for Educators toolkit

The Design Thinking for Educators toolkit was developed in 2011 by the design firm IDEO in partnership

with the PreK-12 independent school Riverdale Country School.[49] The Design Thinking for Educators toolkit that is currently offered to the public for free download is the second version.[50] The Design Thinking for Educators toolkit is a comprehensive resource for educators to use, which includes a "walk-through of the design thinking process complete with examples and a downloadable workbook".[51] The toolkit has been used in academic research to aid in the creation of an "iPad learning Ecosystem".[52] to help design a program to aid at-risk youth in the transition from elementary to secondary school,[52] as well as to redesign libraries.[51]

### AIGA

AIGA has implemented a movement, DesignEd K12, to take designing thinking to schools. This movement is guided by volunteers and there is not a specific program to follow; instead volunteer designers introduce students to the design field and consequently, design thinking. DesignEd K12 intends to motivate students to use design thinking to solve problems; to create a network where designers, students, and educational professionals share best practices; to shape a recommended approach to teaching design; and to cultivate a passion for design among young people.[53] Across the nation, many of AIGA's chapters are working with school districts. The programs range in scope; some mentor students who have shown an interest in design, while other programs offer students the opportunity to explore design and participate in design thinking projects within scheduled classed or through an after-school activity.[53]

### Uses in higher education

Design thinking is currently being taught in "workshops, supplemental training, courses, or degree programs" in over 60 universities and colleges.[54] Design thinking is used by colleges as a way to instruct students on the phases of design, and to help develop innovative solutions to existing problems.[54] The d.school at Stanford University is a well-known design thinking program in higher education, with students from Stanford's departments of engineering, medicine, business, law, and education utilizing the d.school to develop innovative solutions to problems.[55] The University of Kentucky also has formalized instruction on design thinking through its dLab. The dLab serves a multitude of functions from helping schools resolve their issues with design thinking to conducting empirical experiments on design thinking to collaborating with outside organizations to provide issues that plague their organization.[56] Radford University, located in Radford, Virginia, currently offers a Master of Fine Arts (MFA) degree in design thinking.[45] The MFA degree offered is a completely online degree that emphasizes design thinking, design history, design research, design management, and design doing.[57]

### Obstacles to implementing design thinking in schools

The accountability to succeed on high-stakes standardized tests in K-12 environments prevents the implementation of design thinking curriculum. Educators feel that focusing on classic curriculum will better prepare their students to perform well on these exams.[42] Resistance to design thinking also springs from concerns about the appropriateness of applying design thinking to an educational setting. It has been argued that design thinking is best applied by professionals who know a field well.[58] Therefore, K-12 students who are limited by their reduced understanding of both the field and their still developing intellectual capacities may not be best suited to design thinking activities.[58]

Another more subtle obstacle to design thinking in schools may come from members of the academic community who believe design thinking should remain in the milieu of avant-garde companies.[59] Other issues that may prevent the implementation of design thinking in scholastic settings may be a lack of awareness of the field, educators' uncertainty in implementing new approaches to teaching, and lack of institutional support.

Even for institutions that see the value of design thinking, there is the issue of implementing these new approaches to education successfully. Admittedly "creating an effective thinking and successful team learning experience is a sticky wicked problem."[54]

## 5.4 Design thinking in teaching and learning through ICT

The integration of ICT into teaching and learning presents many challenges that go beyond issues dealing with technical implementation. Some researchers have already claimed the limited effects of ICT adoption in learning;[60][61][62] Considering the emphasis and the investment that has been placed on the use of ICT in formal learning settings (schools and higher education institutions) it is important to identify where the problems are. In this regard, some voices of the educational community focus on the methods used for integrating ICT in teaching and learning;.[63][64] In this sense, the adoption of a design thinking mindset is regarded as a promising strategy to develop holistic solutions.

Design thinking in teaching and learning through ICT can be considered as similar activities. First, it's important to acknowledge that the type of problems faced by the educational community when adopting learning technology are unique, ill-defined and do not have clear solutions;.[65][66] This definition corresponds very well to the term *wicked problems* used by the design community.[67] Secondly, similarly to what happens in design, the diversity of actors brings another layer of complexity that should be recognized. In this re-

gard, collaboration between different stakeholders during the design process is another key issue that could contribute to develop more meaningful technologies for learning;[63][64][68]

Design thinking has been outlined as a meaningful approach for facing wicked problems.[9] The adoption of a design mindset helps understand that there can be many solutions for a given situation and that any design requires testing. From this perspective, bringing design thinking to learning design and design expertise to the development process of technological learning solutions can contribute to the creation of more holistic solutions in learning through ICT.[69]

# 6 History

# 7 See also

- Creativity techniques
- Design management
- Design methods
- Design patterns
- Design strategy
- Design tool
- Enterprise architecture
- Lateral thinking
- Metadesign
- Participatory design
- Problem solving
- Reflective practice
- Scenario thinking
- Service design
- Strategic design
- Sustainable design
- Systems thinking
- *Tools for Ideas*
- Transgenerational design
- Universal design
- User experience
- User-centered design
- Wicked problem

**Portals**

- Portal:thinking
- Portal:design

**Lists**

- List of thought processes
- List of creative thought processes

# 8 References


[1] Visser, W. 2006, The cognitive artifacts of designing, Lawrence Erlbaum Associates.

[2] Simon, Herbert (1969). *The Sciences of the Artificial*. Cambridge: MIT Press.

[3] McKim, Robert (1973). *Experiences in Visual Thinking*. Brooks/Cole Publishing Co.

[4] Rowe, G. Peter (1987). *Design Thinking*. Cambridge: The MIT Press. ISBN 978-0-262-68067-7.

[5] Faste, Rolf, Bernard Roth and Douglass J. Wilde, "Integrating Creativity into the Mechanical Engineering Curriculum", Cary A. Fisher, Ed., *ASME Resource Guide to Innovation in Engineering Design*, American Society of Mechanical Engineers, New York, 1993

[6] Faste, Rolf, "Ambidextrous Thinking", *Innovations in Mechanical Engineering Curricula for the 1990s*, American Society of Mechanical Engineers, November 1994

[7] Patnaik, Dev, "Forget Design Thinking and Try Hybrid Thinking", *Fast Company*, August 25, 2009. "...design thinking is any process that applies the methods of industrial designers to problems beyond how a product should look. My mentor at Stanford, Rolf Faste, did more than anyone to define the term and express the unique role that designers could play in making pretty much everything."

[8] Brown, Tim. "The Making of a Design Thinker." *Metropolis* Oct. 2009: 60-62. p. 60: "David Kelley... said that every time someone came to ask him about design, he found himself inserting the word thinking to explain what it is that designers do. The term design thinking stuck."

[9] Buchanan, Richard, "Wicked Problems in Design Thinking," *Design Issues*, vol. 8, no. 2, Spring 1992.

[10] Cross, Nigel. "Designerly Ways of Knowing." *Design Studies* 3.4 (1982): 221-27.

[11] Lawson, Bryan. *How Designers Think: The Design Process Demystified.* London: Architectural, 1980

[12] Ritchey, Tom. "Analysis and Synthesis: On Scientific Method – Based on a Study by Bernhard Riemann - *Systems Research* 8.4 (1991): 21-41" (PDF).

[13] Robson, Mike (2002) [1988]. "Brainstorming". *Problem-solving in groups* (3rd ed.). Aldershot, Hampshire, UK; Burlington, VT: Gower. p. 41. ISBN 0566084678. OCLC 50746638.

[14] Plattner, Hasso; Meinel, Christoph; Leifer, Larry J., eds. (2011). *Design thinking: understand, improve, apply*. Understanding innovation. Berlin; Heidelberg: Springer-Verlag. pp. xiv–xvi. doi:10.1007/978-3-642-13757-0. ISBN 3642137563. OCLC 898322632.

[15] Rittel, Horst; Webber, Melvin. "Dilemmas in a General Theory of Planning. *Policy Sciences* 4.2 (1973): 155-69" (PDF).

[16] Beinecke, Richard. "Leadership for Wicked Problems." *The Innovation Journal* 14.1 (2009): 1-17.

[17] Rowe 1987, pages 40-41

[18] Saloner, Garth. "Innovation: A Leadership Essential *Biz Ed* 2011: 26-30" (PDF).

[19] Cross, Nigel. Designerly Ways of Knowing. London: Springer, 2006.

[20] Koberg, Don, and Jim Bagnall. *The All New Universal Traveller: a Soft-systems Guide To: Creativity, Problem-solving and the Process of Reaching Goals.* Los Altos, CA: Kaufmann, 1981.

[21] "Design thinking chart". Designthinkingblog.com. October 2009. Retrieved 11 March 2015.

[22] Dubberly, Hugh. "How Do You Design: A Compendium of Models".

[23] Jones, John Christopher. *Design Method Vol 4.* New York: John Wiley & Sons, 1992.

[24] Wong, Wiccus. *Principles of Two-dimensional Design.* New York: Van Nostrand Reinhold, 1972.

[25] Gänshirt, Christian. *Tools for Ideas: An Introduction to Architectural Design.* Basel, Boston, Berlin: Birkhäuser, 2007, ISBN 978-3-7643-7577-5

[26] Krasny, Elke (2011). "The Making of Architecture". Graz.

[27] Leborg, Christian. *Visual Grammar*. New York: Princeton Architectural, 2006.

[28] Brown, Tim (2009). *Tim Brown urges designers to think big* (YouTube). TED.

[29] "Design Thinking". *ideo.com*.

[30] "Why the d.school has its limits", *Stanford Daily*

[31] "15 top MBA employers IDEO", *Fortune Magazine* June 05 2012

[32] "When Everyone Is Doing Design Thinking, Is It Still a Competitive Advantage?". *Harvard Business Review*.

[33] Jones, Andrew (2008). *The Innovation Acid Test.* Axminster: Triarchy Press. p. 20.

[34] Leverenz, C. S. (2014). Design Thinking and the Wicked Problem of Teaching Writing. Computers & Composition, 33, 1–12. doi:10.1016/j.compcom.2014.07.001

[35] Bowler, L. (2014). Creativity Through "Maker" Experiences and Design Thinking in the Education of Librarians. Knowledge Quest, 42(5), 58–61.

[36] Leinonen, T. & Durall, E. (2014). Design Thinking and Collaborative Learning. Pensamiento de Diseño Y Aprendizaje Colaborativo., 21(42), 107–115. doi:10.3916/C42-2014-10

[37] Razzouk, R., & Shute, V. (2012). What Is Design Thinking and Why Is It Important? Review of Educational Research,82(3), 330–348. doi:10.3102/0034654312457429

[38] "Research on Design Thinking". *stanford.edu*.

[39] "REDlab- Research in Education & Design". *stanford.edu*.

[40] "Overview - Hasso-Plattner-Institut". *hpi.de*.

[41] http://www.ascilite.org.au/ajet/ajet28/tsai-cc.pdf

[42] http://web.stanford.edu/group/redlab/cgi-bin/materials/IJADE_Article.pdf

[43] Tools at Schools. "Tools at Schools - About". *tools-at-schools.com*.

[44] Tools at Schools. "Tools at Schools". *tools-at-schools.com*.

[45] "Design Thinking: Synthesis 1 - Hexagonal Thinking". *notosh.com*.

[46] http://web.stanford.edu/dept/SUSE/taking-design/presentations/Taking-design-to-school.pdf

[47] "K12 Lab Network". *K12 Lab Network*.

[48] "Creating Design Challenges". *stanford.edu*.

[49] "Vialogues : Annette Diefenthaler, IDEO (Design Thinking & Education)". *Vialogues.*

[50] "Toolkit « Design Thinking for Educators". *designthinkingforeducators.com*.

[51] Bradburn, F. B. (2013). Redesigning Our Role While Redesigning Our Libraries. Knowledge Quest, 42(1), 52–57.

[52] Kernohan, K. (2012). Designing an educational program for at-risk youth in transition from elementary to secondary school: comparing the traditional problem-solving approach to the design thinking approach.

[53] "AIGA - Cultivating design thinking in kids". *AIGA - the professional association for design*.

[54] Goldsman, S., Kabayandondo, Z., Royalty, A., Carroll, M. P., & Roth, B. (2014). Student teams in search of design thinking. Design Thinking Research.

[55] "Our point of view". *d.school*.

[56] "dLab :: The Lab". *uky.edu*.

[57] "About the MFA in Design Thinking". *radford.edu*.

[58] "Why 'Design Thinking' Doesn't Work in Education - Online Learning Insights". *Online Learning Insights*.

[59] "'Design Thinking' and Higher Education". *insidehighered.com*.

[60] Cuban, L., Kirkpatrick, H., & Peck, C. (2001). High access and low use of technologies in high school classrooms: Explaining an apparent paradox. American Educational Research Journal, 38(4), 813-834.

[61] Dynarski, M., Agodini, R., Heaviside, S., Novak, T., Carey, N., Campuzano, L., et al. (2007). Effectiveness of reading and mathematics software products: Findings from the first student cohort. (Publication No. 2007-4005). US: Institute of Education Sciences.

[62] Ross, S. M., Smith, L., Alberg, M., & Lowther, D. (2004) Using classroom observations as a research and formative evaluation tool in educational reform: The school observation measure. In S. Hilberg and H. Waxman (Eds.) New directions for observational research in culturally and linguistically diverse classrooms (pp. 144-173). Santa Cruz, CA: Center for Research on Education, Diversity & Excellence.

[63] Dillenbourg, P., Järvelä, S. & Fischer, F. (2009). The Evolution of Research on Computer-Supported Collaborative Learning. In N. Balacheff & al. (Eds.), Technology-Enhanced Learning. Principles and Products (pp. 3-19). Netherlands: Springer.

[64] Bonsignore, E., Ahn, J. & al. (2013). Embedding Participatory Design into Designs for Learning: An Untapped Interdisciplinary Resource? In N. Rummel, M. Kapur, M. Nathan & S. Puntambekar (Eds.), To See the World and a Grain of Sand: Learning across Levels of Space, Time, and Scale. Paper presented at the 10th International Conference on Computer-Supported Collaborative Learning, University of Wisconsin, Madison, June 15–19 (pp. 549-556). International Society of the Learning Sciences.

[65] Mishra, P. & Koehler, M.J. (2008). Introducing Technological Pedagogical Content Knowledge.In Annual Meeting of the American Educational Research Association, 1-16. New York.

[66] Leinonen, T. (2010). Designing Learning Tools – Methodological Insights. Ph.D. Aalto University School of Art and Design. Jyväskylä: Bookwell.

[67] Rittel, H. & Webber, M. (1973). Dilemmas in a General Theory of Planning. Policy sciences, 4(2), 155-169.

[68] Leinonen, T., Durall, E. (2014). Design Thinking and Collaborative Learning. In Revolution in Education? Computer Support for Collaborative Learning (CSCL). B. Rubia & M. Guitert (Eds.). Comunicar, 21(42)

[69] Leinonen, T., Durall, E., Kuikkaniemi, K., Mikkonen, T., Nelimarkka, M., Syvänen, A. & Toikkanen, T. (2014). Design for Learning: Enhancing Participation in Learning through Design Thinking. In Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2014 (pp. 659-662). Chesapeake, VA: AACE.

[70] "A Brief History of Design Thinking: The theory [P1]". *I think ∴ I design*.

[71] Asimow, Morris. *Introduction to Design.* Englewood Cliffs, NJ: Prentice-Hall, 1962.

[72] Alexander, Christopher. *Notes on the Synthesis of Form.* Cambridge: Harvard UP, 1964.

[73] Archer, L. Bruce. *Systematic Method for Designers.* Council of Industrial Design, H.M.S.O., 1965.

[74] Jones, John Christopher. *Design Methods.* New York: John Wiley & Sons, 1970.

[75] Gordon, William J. J. *Synectics, the Development of Creative Capacity.* New York: Harper, 1961

[76] Osborn, Alex F. *Applied Imagination: Principles and Procedures of Creative Thinking.* New York: Scribner, 1963.

[77] "L. Bruce Archer". *oxfordreference.com*.

[78] Alexander, Christopher. "The State of the Art in Design Methods." DMG Newsletter 5:3 (1971): 3-7.

[79] Jones, John Christopher. "How My Thoughts about Design Methods Have Changed during the Years." *Design Methods and Theories* 11.1 (1977): 45-62.

[80] Rittel, H., 1984, "Second-Generation Design Methods." *Developments in Design Methodology.* N. Cross (Editor), John Wiley & Sons, UK pp. 317-327.

[81] Cross, Nigel. "Forty Years of Design Research." Design Studies 28 (2007): 1-4.

[82] Archer, L. Bruce. "Whatever Became of Design Methodology?" *Design Studies* 1.1 (1979): 17-20.

[83] Hubka, Vladimir, and W. E. Eder. *Principles of Engineering Design.* London: Butterworth Scientific, 1982.

[84] Beitz, Wolfgang, Ken M. Wallace, and Gerhard Pahl. *Engineering Design.* London: Design Council, 1984.

[85] French, M. J. *Conceptual Design for Engineers.* London: Design Council, 1985.

[86] Cross, Nigel. *Engineering Design Methods.* England: Wiley, 1989.

[87] Pugh, Stuart. *Total Design: Integrated Methods for Successful Product Engineering.* Wokingham, England: Addison-Wesley Pub., 1991.

[88] Lawson, Bryan. *How Designers Think: The Design Process Demystified.* London: Architectural, 1980.

[89] Schön, Donald A. *The Reflective Practitioner: How Professionals Think in Action.* New York: Basic, 1983.

[90] "The New Bauhaus continues today as IIT Institute of Design". *IIT Institute of Design—Beta website*.

[91] Nonaka, Ikujirō, and Hirotaka Takeuchi. The Knowledge-creating Company: How Japanese Companies Create the Dynamics of Innovation. New York: Oxford UP, 1995.

[92] Florida, Richard L. *The Rise of the Creative Class: and How It's Transforming Work, Leisure, Community and Everyday Life.* New York, NY: Basic, 2002.

[93] Pink, Daniel H. *A Whole New Mind: Why Right-brainers Will Rule the Future.* New York: Riverhead, 2006.

[94] Martin, Roger L. *The Opposable Mind: How Successful Leaders Win through Integrative Thinking.* Boston, MA: Harvard Business School, 2007.

[95] Gladwell, Malcolm. *Outliers: the Story of Success.* New York: Little, Brown and, 2008.

[96] Brown, Tim, and Barry Kātz. *Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation.* New York: Harper Business, 2009.

[97] Lockwood, Thomas. *Design Thinking: Integrating Innovation, Customer Experience and Brand Value.* New York, NY: Allworth, 2010.

[98] Kumar, Vijay. *101 Design Methods: A Structured Approach for Driving Innovation in Your Organization.* Hoboken, NJ: Wiley, 2012.

[99] Keeley, Larry, Helen Walter, Ryan Pikkel, and Brian Quinn. *Ten Types of Innovation: The Discipline of Building Breakthroughs.* Hoboken, NJ: Wiley, 2013.

[100] Erwin, Kim. *Communicating the New: Methods to Shape and Accelerate Innovation.* Hoboken, NJ: Wiley, 2014.

[101] Moggridge, Bill. *Designing Interactions.* Chapter six. The MIT Press; 1 edition (October 1, 2007).

[102] "Master's in Learning & Organizational Change at Northwestern University :: Why Master's in Learning and Organizational Change". *northwestern.edu*.

[103] "Faculty Members Advise Design for America Group". *northwestern.edu*.

[104] "Extracurricular Design-Based Learning: A New Model for Innovation Education". *northwestern.edu*.

[105] "Design Camp". *IIT Institute of Design—Beta website*.

[106] "MFA in Design Thinking - Online Master's Degree - Radford University". *radford.edu*.

[107] "Girls Driving for a Difference". *Girls Driving for a Difference*.

[108] Cole, Samantha (3 March 2015). "How four women in an RV plan to change young girls' lives: this summer, four Stanford students will bring design-thinking workshops to middle-school girls at summer camps across the country". *Fast Company*. Retrieved 11 March 2015.

# 9 Further reading

- Cross, Nigel. *Design Thinking: Understanding How Designers Think and Work.* Oxford UK and New York: Berg, 2011.
- Cross, Nigel. *Designerly Ways of Knowing.* London UK and Boston MA: Birkhauser Verlag AG, 2007.
- Gänshirt, Christian. *Tools for Ideas. An Introduction to Architectural Design*, translated by Michael Robinson, Basel, Boston, Berlin: Birkhäuser Verlag AG, 2007, ISBN 978-3-7643-7577-5.
- Faste, Rolf. "The Human Challenge in Engineering Design." *International Journal of Engineering Education*, vol 17, 2001.
- Kelly, Tom. *Ten Faces of Innovation.* London: Profile, 2006.
- Lawson, Bryan. *How Designers Think.* Oxford UK: Architectural Press/Elsevier, 2006.
- Liedtka, Jeanne. *Designing for Growth: A Design Thinking Tool Kit For Managers.* Columbia University Press, 2011, ISBN 0-23-115838-6
- Liedtka, Jeanne. *Solving Problems with Design Thinking: Ten Stories of What Works.* Columbia University Press, 2013, ISBN 0-23-116356-8
- Lockwood, Thomas. *Design Thinking: Integrating Innovation, Customer Experience and Brand Value.* New York, NY: Allworth, 2010.
- Lupton, Ellen. *Graphic Design Thinking: Beyond Brainstorming.* New York, NY: Princeton Architectural Press, 2011. ISBN 978-1-56898-760-6.
- Martin, Roger L. *The Opposable Mind: How Successful Leaders Win through Integrative Thinking.* Boston, MA: Harvard Business School, 2007.
- Nelson, George. *How to See: a Guide to Reading Our Man-made Environment.* San Francisco, CA: Design Within Reach, 2006.
- Pink, Daniel H. *A Whole New Mind: Why Right-brainers Will Rule the Future.* New York: Riverhead, 2006.
- Plattner, Hasso et al. *Design Thinking: Understand, Improve, Apply.* Berlin; Heidelberg: Springer, 2010.
- Rittel, Horst, and Melvin Webber. "Dilemmas in a General Theory of Planning." *Policy Sciences* 4.2 (1973): 155-69.
- Schön, Donald. *The Reflective Practitioner: How Professionals Think In Action.* New York: Basic Books, 1983.
- Schön, Donald. *Educating the Reflective Practitioner.* San Francisco: Jossey-Bass Inc., 1987.

# 10 Text and image sources, contributors, and licenses

## 10.1 Text

- **Design thinking** *Source:* https://en.wikipedia.org/wiki/Design_thinking?oldid=694566372 *Contributors:* Booyabazooka, Ronz, Coren, Klemen Kocjancic, Paulgiron, Pearle, Nigel Cross, Woohookitty, Anomalogue, BD2412, Threefour, Rjwilmsi, Bgwhite, Jpbowen, SmackBot, Jab843, Turadg, TimBentley, Ehheh, Andy penaluna, Steven Forth, Zarex, Dhwestmoreland, Vectro, Yaris678, Gogo Dodo, Letranova, AndrewCarey, The Transhumanist, Leolaursen, Magioladitis, Schuhm, Dilane, Adapt, Oicumayberight, DGG, Mqchen, Thyer, Philip Trueman, Samoore, Optigan13, Abhoopat, Barkeep, Chimin 07, Yintan, Gyokomura, Leranedo, EoGuy, Wrh25, Niceguyedc, DWmFrancis, Bjdehut, Bristolian46, M8leung, Addbot, Nicearma, MrOllie, Debresser, Tassedethe, Yobot, Nikiburri, David burney, Citation bot, GB fan, Xqbot, Wantanabe, Omnipaedista, Equguru, Samwb123, Themeparkgc, FrescoBot, Dosigner, Spartakan, Flipchart marker, Cnwilliams, Lotje, Stegop, Ohair, Onel5969, John of Reading, Prof John Wood, Mariaflags, Aldnonymous, Btstuck, ClueBot NG, Jack Greenmaven, Naish84, Pyrsmis, Wakeup1, Up4201, Widr, Von nichthoven, Helpful Pixie Bot, BG19bot, Tgdmatters, Tomijun, Gmcbjames, Johannes.milke, ShonaBose, BattyBot, Moremushroom, Designergene, Mmj2love, Lebaronmatthew, Biogeographist, Jodosma, Goyah, AddWittyNameHere, Angelicabastos, Skywicke, RocioGarciaRamos, Skr15081997, Frogmilk, Xisto01, Ach8, Lsfx, Mockingbird3, Brettnewman, Abbyssoul, Edugama, Inkjuice, Grassview, Yamzy333, Abigailripstra, Ashkababel, Madhatter979, Andrew Coffin 77, Caroline maree, Hwesselius and Anonymous: 100

## 10.2 Images

- **File:DesignThinking.ogv** *Source:* https://upload.wikimedia.org/wikipedia/commons/f/fd/DesignThinking.ogv *License:* CC BY 3.0 *Contributors:* Own work *Original artist:* Brettnewman

## 10.3 Content license

- Creative Commons Attribution-Share Alike 3.0