Design thinking and its application to problem solving

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ABSTRACT: In this article, the authors implement the design thinking paradigm as a method to find solutions for specific problems and challenges within higher education. This approach was triggered by the continuous changes in technology and the requirements of the outcome-based curriculum in regard to graduate attributes. The authors also address the question as to whether researchers should be problem focused or solution focused in the process. Problem-oriented thinking is closely linked to critical thinking, and questions like *what*? and *why*?, whereas solution-focused thinking is linked to creativity and the question *how*. In this context, design thinking should be thought as a form of solution-based thinking, which is implemented to produce creative future results and/or creative resolutions to wicked problems. This article identifies how design thinking was implemented to provide innovations in outcome-based teaching and learning considering aspects, such us curricula, pedagogy, assessment methods and teaching spaces. The main goal was to improve graduate attributes and, as a consequence, the academy to industry transition. Using case studies to accommodate the new generation of learners, the authors argue in the article that user-oriented and outcome-based oriented design thinking is the suitable paradigm to ensure that these initiatives are successful.

Keywords: Engineering design, design thinking paradigm, wicked problems, outcome-based curriculum, experimental thinking, solution-focused problem solving

INTRODUCTION

This article identifies opportunities for design thinking, and how the design thinking paradigm was implemented to find solutions for problems associated with curriculum, pedagogy, assessment, learning space and the new generation of learners. Design thinking was used as a human-centered, open-ended problem-based approach to transform the way teaching and learning is conducted in engineering education, and to solve the different challenges that instructors and students are facing in the context of digital learning and of outcome-based curriculum [1][2]. As indicated by Pusca and Northwood [3], and as Grant Wiggins and Jay McTighe mentioned in their book *Understanding by Design*:

> *Teachers are designers. An essential part of our profession is the design of curriculum and learning experiences to meet specified purposes* [4].

As a starting point, the authors address the question as to whether researchers should be problem focused or solution focused in the process. An analysis is made based on the schematic representation in Figure 1. *Why* is the *guiding vision* of Riddell [3][5]. The questions *why* and *what* identify opportunities for design thinking and contribute to the formulation of the (design) problem to be addressed. Several examples that can be considered as open-ended problems related to academic education are indicated in Figure 1. The question *how* identifies design thinking as the enabler of forward-thinking ideas to find a creative solution to the problem. As a result of such analysis, it was concluded that problem-oriented thinking is closely linked to critical thinking, and questions like *why*? and *what?* help with the formulation of the problem, whereas solution-focused thinking is linked to creativity and as a result to the question *how*. Todd Henry in his book *The Accidental Creative* considers the *how* to be the creative strategy [6]. Since design thinking is a creative strategy to produce creative future results and/or creative resolutions to problems, it should be thought as a solution-focused thinking strategy.

In a learning-centred campus, student learning is the most significant goal of the university [2][7]. Thus, students should always be kept first in mind when addressing the *why* and *what* questions to formulate the problem, as well as the *how* when deciding on creative strategies to identify the best solution. Design thinking is considered as an *integrative* process [8], and is *…less about thinking and more about doing*, as mentioned by Baert [9]. In an integrative learning environment, empathy should be part of design thinking, since it is important to *…understand the experience, situation, emotion of the person you are working for* - the students [9].

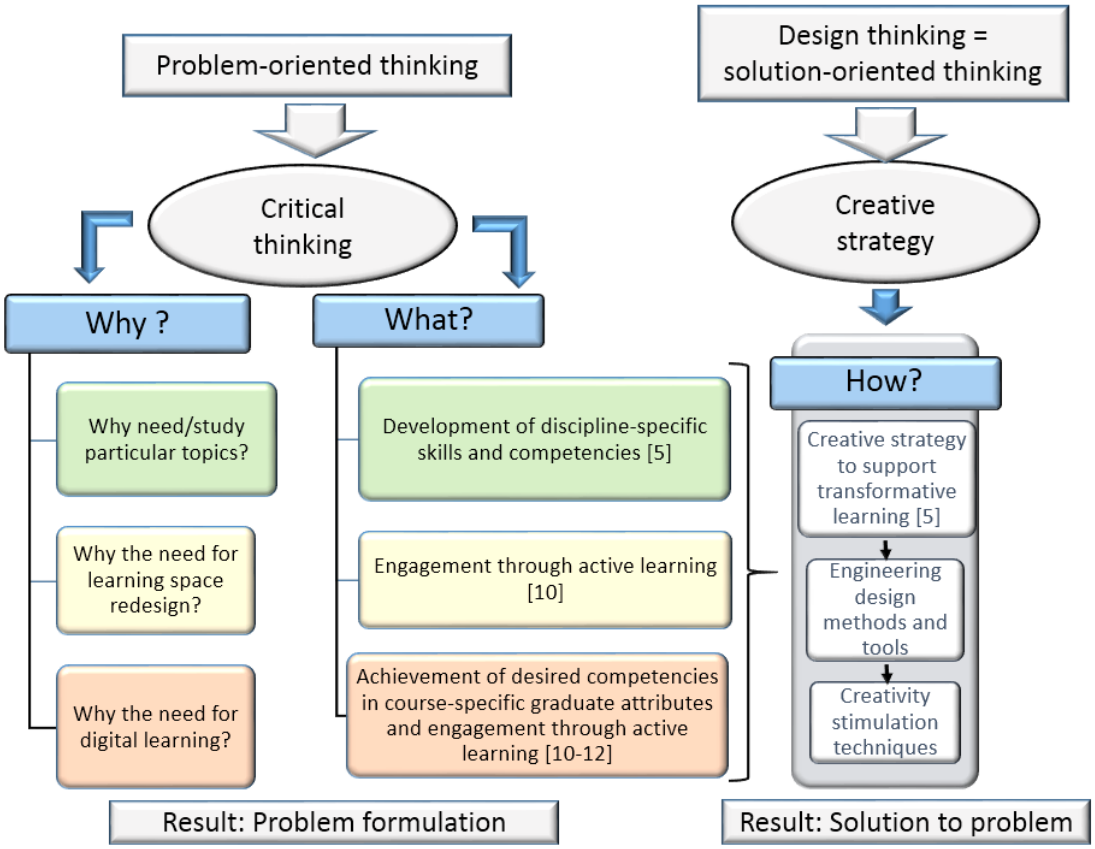

Figure 1: Is design thinking problem focused or solution focused?

DESIGN THINKING PARADIGM AND WICKED PROBLEMS

The term *design thinking* is often used as a unique approach to solving problems in innovative ways. Researchers in various disciplines are using the principles of design to solve problems. Tim Brown in his book *Change by Design: how Design Thinking Transforms Organizations and Inspires Innovation* has explored *design thinking* [10]. *Design thinking*, based on the same principles used by designers to produce innovative solutions for engineering problems, is considered by Brown to be the paradigm for solving complex problems regardless of the field of activity. According to Brown:

> *Design thinking has its origins in the training and the professional practice of designers, but these are principles that can be practiced by everyone and extended to every field of activity* [10].

Kimbell also explains that design thinking *has been appropriated in a variety of professions (e.g. business and sciences) to solve disciplinary problems in seemingly new ways* [11]. In the same context, Piotrowski explains:

> *Businesses are seeing that the process of design can bring innovative thinking to problem solving within the corporate environment. This methodology is called design thinking* [12].

Cairnes [13] and Northwood [14] pointed out that we are living in a *world of rapid discontinuous change and wicked problems*. As mentioned by Buchanan [8] the wicked problems approach was formulated by Rittel in the 1960's. Also, in the first published report of Rittel's idea, wicked problems are defined as:

> *A class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing* [15].

As described by Rittel, design thinking and decision making is not a simple linear process when applied to solving wicked problems. The proponents of the linear process in design thinking consider the design process as *divided into two distinct phases*: structuring the problem identification and formulation, and structuring the search for solutions [8]. The first phase is considered an analytic sequence in which the designer determines all of the elements of the problem and specifies all of the requirements and the constraints. Problem identification and formulation is a very important phase, since a wrongly formulated problem will not lead to a successful design solution. The second phase, structuring the search for a solution, consists of synthesis and analysis sequences in which several possible concepts are evaluated to find the best solution for the problem. A comparison between the linear model for the design process and the wicked problem approach by Rittel, is presented in Figure 2. Buchanan argues that *the wicked-problem approach has remained only a description of the social reality of designing rather than the beginnings of a well-grounded theory of design* [8].

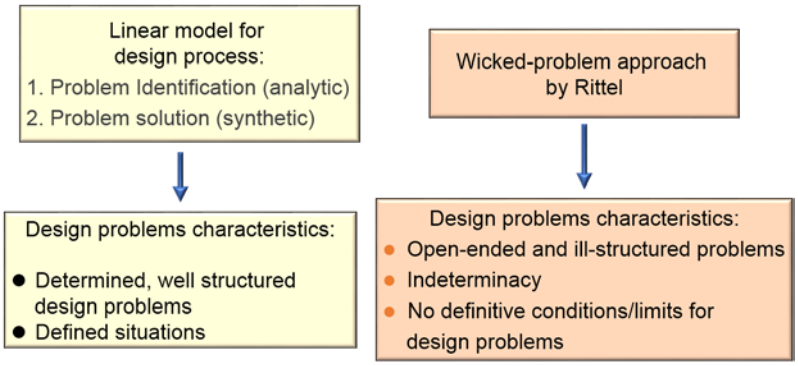

Figure 2: Design thinking as a linear process and the wicked-problem approach.

In an opinion piece on design thinking, Johnson indicates that its proponents consider that it is particularly well-suited for solving *wicked problems* [16]. He also argue that:

> *Design thinking is changing the way some academics approach teaching and research, the way architects design classrooms and how leaders seek to solve the world's most persistent problems* [16].

DESIGN THINKING IN ENGINEERING - A TOOL FOR PROBLEM SOLVING

Design educators use the term to explain how design thinking paradigm can be implemented to improve lives, solve problems and enable collaborations with non-designers [17]. Design methodology - as a tool for creative problem solving in engineering, has developed over time. Pahl and Beitz [18], Pugh [19], Voland [20] and Ullman [21] are few of the known authors of books on engineering design methods and methodology. Design thinking as a process, is a similar approach and descriptor to what engineering designers do. As Kelley mentioned [8][22]:

> *We moved from thinking of ourselves as designers to thinking of ourselves as design thinkers.*

Figure 3 is a schematic representation for the engineering design process, as the design thinking paradigm in engineering - an *effective problem-solving algorithm* [20][21]. This is a model-based definition for design thinking, as a sequential process.

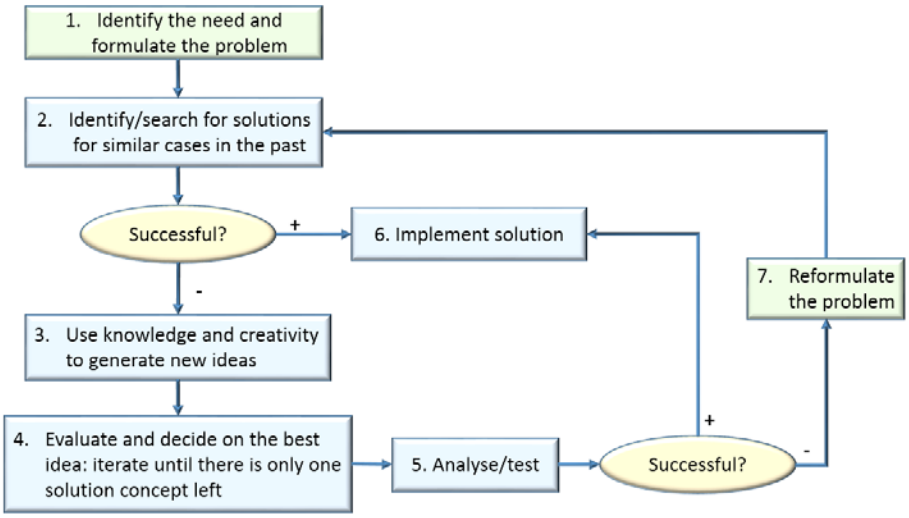

Figure 3: Schematic of the design thinking paradigm as an engineering design process.

The process starts with the need for identification and formulation of the problem, including any associated constraints. This first step is very important, since a well formulated problem is necessary in order to find the desired solution. As mentioned by Hall [23], and according to Horst Rittel's essay *The Reasoning of Designers* [24], there are often complex problems that require *disorderly reasoning*:

> *A design problem keeps changing while it is treated, because the understanding of what ought to be accomplished, and how it might be accomplished is continually shifting. Learning what the problem is IS the problem* [24].

First, the designer tries to associate the problem with similar cases from the past. If this approach will not provide any solution, the next step is to generate new ideas using knowledge and creativity as a form of experimental thinking.

Evaluation of these ideas using a decision matrix will lead to one solution that will be further analysed and tested. If successful, it will be implemented. If not successful, the problem needs to be reformulated, and the process repeats. This is an iterative process, i.e. a loop method. The main iterative loop with two iterations is shown in Figure 4.

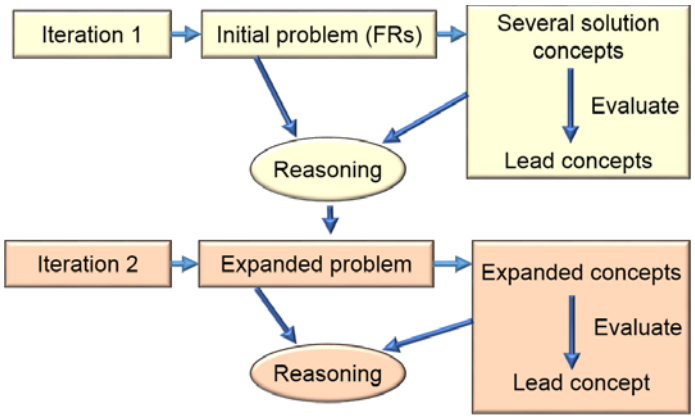

Figure 4: The main iterative loop with two iterations for the evaluation stage in design thinking [25].

This model-based definition gives a very clear and easy to understand description of what design thinking is. In fact, the concept is very complex and somewhat different from the design thinking process associated with other non-engineering activities. The difference consists in the tools and methods employed during the five main stages, stages 2 to 6 in Figure 3. The main common aspect is the use of creativity and creativity stimulation techniques, like brainstorming, analogy, inversion or checklisting using trigger questions.

Cross argues that there are *forms of knowledge special to the competencies and abilities of a designer* [26]. This has been demonstrated by the present authors in several applications involving the adaptive use of engineering design methods to solve non-engineering issues, such as course design for outcome-based curriculum [25], learning space [7], and assessment methods design [27][28].

DESIGN THINKING FOR CURRICULUM DEVELOPMENT

The suitability of the design thinking paradigm as an adaptive use of engineering design methods and tools to solve complex problems was demonstrated by the authors through empirical research conducted in the context of curriculum development [25][27][28]. The adaptive use of engineering tools has proven its effectiveness through the achievement of desired outcomes for problems associated with curriculum development regarding new and improved course design for an outcome-based curriculum. They also provide a qualitative evaluation and future opportunities for improvement, as described in Figure 5.

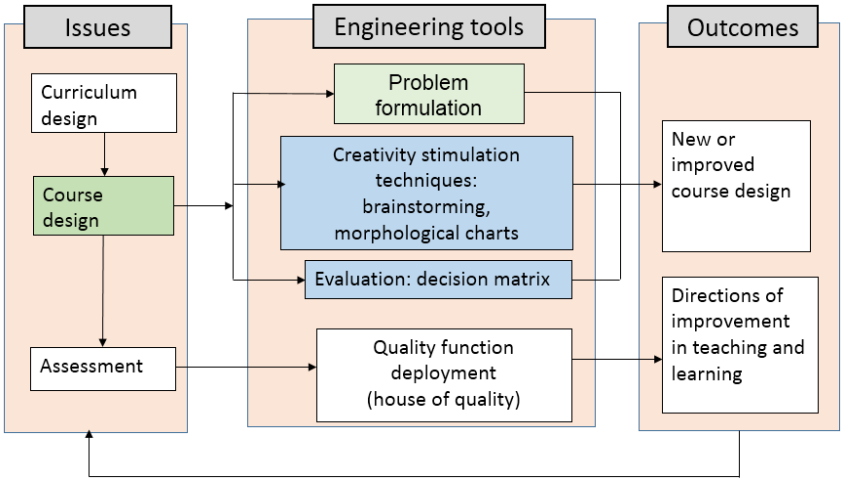

Figure 5: Design thinking for outcome-based course design.

Woods claims that findings in the literature, as well as his experience with methods for solving complex problems at McMaster University, have proven the effectiveness of the use of basic problem-solving strategies [29][30]. Douglas et al also discuss the problem solving strategies or heuristics used by engineers and support Woods' strategy based on empirical research [31]. It is what Woods [29] calls a *basic strategy* for solving complex problems - typically start with an *awareness of problem* stage, then a *definition stage* and close with an *evaluation* or *verification* stage. This strategy is composed of six discrete steps, which can be used in an iterative manner, similar with the design thinking paradigm proposed in Figure 3 and used by the authors to solve open-ended problems associated with curriculum design.

Some authors do not believe that problem-solving strategies as the design thinking paradigm described in this article are useful, because of the linearity (or step-by-step progression) [31] and the indeterminacy associated with the wicked problems [8][15].

This article indicates that the engineering design method can be considered as a design thinking paradigm both to solve any complex problems, because it provides a logical understanding of the design process, and a guide to achieve a solution to the problem. In medicine, there is also research to show the adaptive use of design heuristics as a useful strategy for problem solving and decision making [32], and the authors consider *the engineering study of* intuitive design, *that is, the design of transparent aids for making better decisions*. Visser also explores to what extent design thinking involves similar or different processes when implemented with different activities or disciplines [33]. Johnson explains why principles of design should be used in various disciplines to solve complex problems:

> *…with its emphasis on teamwork and its problem-based approach, design thinking is particularly well-suited to solving* wicked problems - *those big, ill-defined, complex, multifaceted issues that don't have a clear solution* [16].

CONCLUDING REMARKS

The authors support the suitability of design thinking paradigm as an adaptive use of engineering design methods and tools to solve complex problems, and this was demonstrated through empirical research conducted in the context of curriculum development to provide innovation in curriculum development.

The authors also indicate that design thinking should be thought as a form of experimental thinking that is solution focused, and may be implemented to produce creative solutions to wicked problems. As mentioned by Pasricha:

> *The goal is not to be perfect. The goal is just to be better than before* [34].

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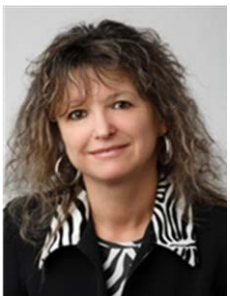
BIOGRAPHIES



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