APPROACHES TO A CROSS-CULTURAL ENGINEERING DESIGN THEORY

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ABSTRACT
Engineering Design Theory as an integral part of design education serves the purpose of structuring actions and thinking processes in order to increase the efficiency of development processes and the quality of developed products. In many institutions in Europe and the U.S.A., problem-oriented process models based on the approach of functional decomposition have complemented teaching approaches that rely on studying standard solutions such as machine elements. If one assumes that these models have been designed to suit the thought habits and educational traditions in the cultural spheres of their origin, their validity in the context of the globalization of engineering education must be discussed. Especially with regards to "Western" and "Asian" cultures, Nisbett [1] substantiates the existence of profound cognitive differences that might be relevant for design education and practice. Summarizing some of Nisbett's assertions, Westerners are more likely to rely on categorizing and individualizing objects and applying formal logic in any situation, whereas Asians prefer not to disentangle objects from their context in favour of a more holistic view of the world.
This paper explores the consequences of such cultural differences in the context of product design and development to add plausibility to the authors' own observations from teaching practice with students from China, Germany, South Korea, Thailand and the United Kingdom. The discussion focuses on the applicability of the established model of the Engineering Design Process, narrowing the scope of Design Theory but broadening on the view that different design practices are attributed solely to differences in social interactions.

Keywords: Design education, design theory, design process, intercultural collaboration

1 INTRODUCTION

Western design and engineering perspectives embody the traditions of technology development combined with creativity. Approaches to engineering education range from master pupil and apprentice, to traditional science and studio based. Modern undergraduate degrees in engineering include a combination of technical and transferable skills (as defined, in the case of the United Kingdom, for the recognition of professional engineers by UK-SPEC [2], and in the United States by ABET [3]). The National Academy of Engineering (2004) [4] define the requisite attributes of the engineer of 2020 to continue to include strengths in science and mathematics, practical ingenuity, creativity, good communication and mastery of the principles of business and management.
Chinese design and engineering can be characterised by convergence between the sciences and the rich cultural heritage available, while in Korea an emphasis is placed on creating industrial and economic value by merging humanities, science and the arts. These statements have strong linkages and the differences that exist are highlighted in the subtleties of words such as convergence, merging and combination. In addition different regions of the world are tackling and developing their engineering and design sectors with diverging approaches.
In China, the government education investment is in developing design schools with 1000 schools over the last decade, producing more than 250000 design graduates a year. Design represents the third most popular university subject in China. In South Korea design courses in universities are over-

subscribed and the Design Declaration of the 21st Century Korea (2008) articulates the role of design as creating industrial and economic value by merging humanities, science and the arts. Governmental support for aesthetic design is strong in both South Korea and China with movements embodied in the slogans 'Creative Korea by Design' and to 'Designed in China' [5].

Increasing numbers of students from Eastern Asian countries have been graduating in Europe and the U. S. and moving on to teach at institutions in their home countries, passing on teaching approaches and thinking models. International collaborations between institutions and exchanges of lecturers support that trend. The "World Class University" subsidy program aims at satisfying the growing demand of resources and content by encouraging international scholars to research and teach in Korean institutions. As a result of these trends, Western approaches to design methodology are used in Asian design programs.

This would not seem noteworthy, if the taught principles were indeed as universal as Western scholars deem them, but there is evidence that the different traditions of thought of Asia and the West impacts how reality is conceived and modelled, which is very relevant for design thinking, arguing, decision taking and structuring activities especially in the design context. This paper explores the consequences these later findings have on Engineering Design education and practice and ultimately tries to add plausibility to the authors' own observations from teaching practice.

In line with [1], the term "Asian" is used in this paper to refer to groups of individuals from principally China, Korea and Japan, but also to a lesser degree Southeast Asia. The authors are aware of differences between these nations' cultural differences as well as the differences between the individuals involved, but the generalization seems appropriate both because of the relative cultural differences to "Westerners" and the fact that some Asian student groups involved in the studies are indeed of diverse cultural background. Likewise, "Westerners" refers mainly to groups of individuals from Europe, the British Commonwealth and the US.

2 BASIC PRINCIPLES

2.1 Thinking in design, cultural aspects

The mind enables us to process significant quantities of information, and critically evaluate and consider this information in order to define and elicit a response to solving problems. [6] asserts that because the mind works analogically, making short-cuts on the processing of information, rather than logically this acts to stifle creative solutions. Rigorous thinking and analysis of information enables us to test facets of information and ideas and this can lead to much more robust solutions than we might otherwise adopt because of our tendency to adopt any solution that makes the problem go away. [7] identifies three characteristic thinking styles in education: analytical thinking, normally associated with the sciences; artistic thinking, normally associated with humanities subjects; design thinking, normally associated with industrial design, architecture and design engineering. In engineering each mode has an important role, and programmes that concentrate on just one perhaps serve to stymie the engineer.

Socio-cultural effects have a significant influence on the development of our thinking and behaviours. The basis of modern thinking in the Western World has its roots in three principal philosophers and thinkers: Socrates, Plato and Aristotle. The combination of contributions from Socrates, dialectic and argument, Plato, theory of forms and Aristotle, identity, systematic inclusion and exclusion logic, and the resulting developments of thought through history give us a thinking system that is largely based on a search for truth that is determined by argument. By argument un-truths are revealed and the 'truth' is arrived at. Much western thinking is concerned with what is, determined by analysis, judgement and argument.

Nisbett [1] finds evidence in such philosophical and historical facts and backs it up with numerous studies and psychological experiments to support the thesis that there indeed is a Western system of thought which is fundamentally different to the Asian, which is mainly influenced by ancient Chinese philosophy, Taoism, Confucianism and Buddhism. It is argued that the existence of these two cultural spheres might originate from ecological circumstances that support certain economical structures which in turn influence social structures, attention disposition, metaphysics, epistemology and finally cognitive processes. Certain reinforcing effects result in both modern societies adhering to ancient principles, even if there is an increasing exchange of ideas.

The underlying difference in principle is that Westerners tend to view objects as isolated entities whereas Asians attend to objects in their broad contexts. This seems to be mirrored in all aspects of life, such as

- social life, where Westerners insist more on freedom of individual action and distinctiveness whereas Asians prefer collective action and blending harmoniously with the group;
- habits of organizing or modelling the world, where Westerners prefer to define categories or classes to group objects that share certain properties whereas Asians prefer to avoid categorization and seeing each specific object as the sum of all its relations within a context
- explaining the causality of events, where Westerners prefer to apply rules specific to the category an object belongs to, therefore seeing the cause as object-intrinsic whereas Asians tend to find multi-causal explanations resulting from the environment;
- the use of formal logic, which Westerners more readily apply in situations of everyday life as Asians;
- the application of dialectical approaches, with Asians more inclined to find a "Middle Way" when confronted with contradiction and Westerners insisting on favouring one belief and discarding the other.

2.2 Engineering Design Process

One of the most commonly agreed on approaches in the field of Engineering Design Theory is the idealized linear "Engineering Design Process" ("EDP") that emphasizes a thorough exploration of the design problem, mainly by means of functional decomposition, before any decisions are taken towards the design solution. The underlying principle is the assumption that it is possible and meaningful to describe the product to be developed as one overall function (input, operator, output) that can be broken down into a structure of corresponding sub-functions ("function structure"), thereby abstracting and analyzing the design problem. A solution is then identified for each sub-function separately ("sub solution"). A synthesis of the solutions according to the function structure will result in an overall "concept solution", which is consequently concretized and detailed, thereby taking all the restrictions and requirements into account that had to be ignored during the initial abstraction process. It is interesting to note that as there is only a minor transition from function to solution, the function structure is not only an abstract model of the design problem, but also of the solution, i. e. technical product to be developed, Figure 1.

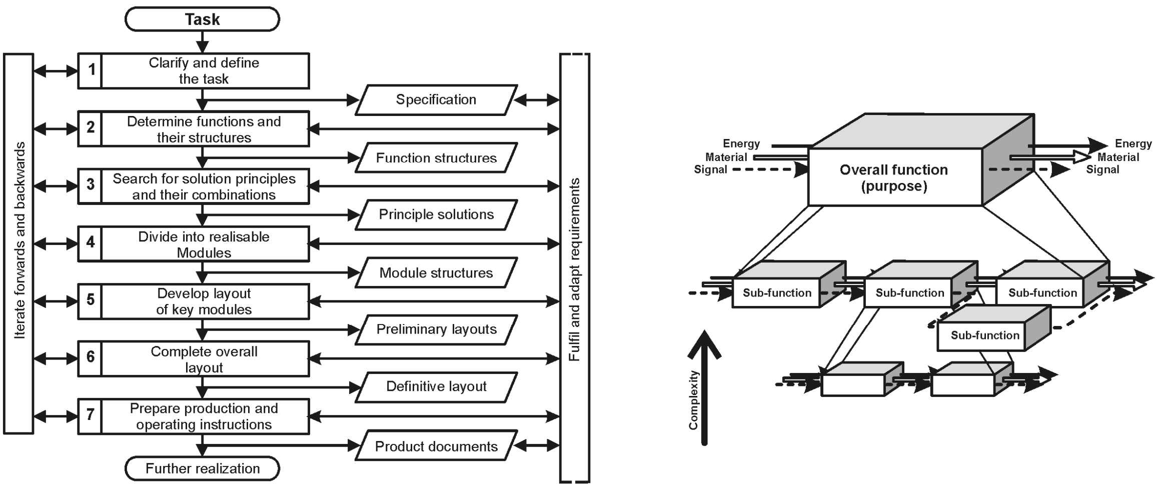

Figure 1. Engineering Design Process (left) and concept of functional decomposition according to [8]

Summing up the underlying principles of this approach to design:

- *abstraction*: it is possible and meaningful to describe an object by stripping away all properties but the essential ones that define the object
- *analysis/decomposition*: One object can be broken down into many objects. They have relations (energy, material and/or signal flows), but are discrete.
- *single-cause causality, linearity*: Even if some representations of the process model imply iteration between the process steps, the principle is that only one track is followed if the

argumentation in each process step is carried out flawlessly.

- *systematic variation and selection*: This principle is not as obvious from the process representation as the others, but as essential: Each creative step should not result in one proposition but several ones. These variants are then discussed and the most appropriate selected for further development.

The purposes of these principles seem plausible. *Abstraction* and *variation* aim at avoiding the pitfalls of a premature fixation on ideas, most often in the form of existing solutions or products. The concept of *analysis* and the *linear workflow* reduce the complexity of the problem and decision taking processes. Finally, *systematic variation* serves to increase the quality of the solution and to cover the project, for example by ensuring that fallback solutions are always at hand.

The process model's applicability has always been criticized by practitioners as either being to simple to actually assist handling the complexity of "real-world" problems or over-emphasizing conceptual design where most design challenges in industrial practice would be classified as "embodiment design" type problems. It is these practitioners that often rather rely on gradual improvement of existing solutions (the solution-oriented approach). But also scholars acknowledge the fact that engineers cannot be trained by Design Methodology alone; this teaching approach has to be complemented by application examples - ideally, it should be demonstrated, how the correct application of the theoretic models and methods would lead to a given solution that has proven to be a best-practice example.

With regards to the tradition of thought, the design process itself is a brilliant example of a "form" in the sense of Plato's Theory of Forms, which asserts that non-material abstract "forms", and not the material world of change known to us through sensation, possess the highest and most fundamental kind of reality [9]. Following this philosophical system, each actual design process is to the Design Process what a copy or shadow is to an original - only an incomplete and distorted copy. If seen in this tradition, the Design Process is indeed universally applicable; it was never meant to be a code of practice that has to be followed meticulously. It is therefore concluded that the outlined approach to problem solving and design education can be rather useful if the user accepts that it requires the ability and willingness to structure one's own thinking processes accordingly and ultimately, practice and experience to successfully project the simple models into complex reality. This experience must also allow the user - possible subconsciously - to abandon the process if it is not reasonable in a given context.

The question of interest, which will be explored hereafter, is, if there are detectable differences with regards to how well Design Methodology as a tool is suited to support Asians and Westerners in typical Design situations. If there is relevance to Nisbett's findings, Asians should find it substantially more difficult or at least less intuitive to use this tool, which has been demonstrated to be structured as specific to Western thinking patterns, within a design project.

2.3 Lessons learned from cross-cultural design teaching

Experience from years of teaching design-related classes in an intercultural context allow for some generalized statements on the differences of acceptance of the Engineering Design Process between Asian and Western students. As the awareness of this topic has only arisen over the last years, quantifiable data has not been systematically collected. Nevertheless, examination results and project notes support subjective findings of the authors of this paper.

Direct comparisons could be drawn at RWTH Aachen University between groups of German students and groups of Chinese and Southeast Asian students, because the same approach on Design Methodology has been taught in German and English/international programs since 2003. The English version of this course, mostly attended by Chinese and Indian students in Aachen, is additionally taught in an affiliated college in Bangkok, Thailand[1]. After eight years of teaching both courses side by side, the generalized conclusion seems justified that Chinese and Southeast Asian students have more trouble connecting the methodology to specific use cases than their German counterparts. In examinations at the end of each semester, the Chinese students on the Aachen campus often failed to outline the design process over a given example, even if questions on contents discussed in the lecture revealed they prepared well for the exam. German students have fewer problems explaining the

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overall approach, while generally revealing a lack of depth when asked to reproduce details such as an exact terminology. Interesting insights could also be gathered by the project work students had to do on the Bangkok campus for assessment purposes. In the early years, each student was asked to separately work on a design problem of agricultural engineering by following the taught process. This approach was a frustrating failure. Almost none of the students were able to make the transition from one process step to the next without specific instructions. When the project work was switched to team work, the outcome dramatically changed for the better. The team was able to produce brilliant results independently, mostly in the form of impressive CAD models. However, when asked to demonstrate how design decisions were reached or how the design process was applied, the answer was usually a shy smile. Only when specifically pressed for the team would produce the documentation of the application of any method, but it was in most cases obvious that it only worked towards reproducing a design decision that had already been reached. It seems that Southeast Asian students see little practical value in applying Design Methodology when the required outcome of a project is a CAD model. The Chinese co-author confirms that, even if Design Methodology is a common approach in China, a lot of students seem confused about what they learned. The Korean co-author similarly states that students at Hongik University seem somewhat unconvinced by the approach, but points out this might be attributed at least in part to the professors' relative lack of experience with it.

Observations of team work in international teams seem to confirm a different acceptance of the process model. In a collaborative course between RWTH Aachen and Hongik University that is currently going through its fourth run, international teams of Korean students of transportation design ("styling") and Korean and German engineering students compete over the period of one semester to produce the most convincing vehicle concept. As the Korean and German team mates are physically separated in the first project phase, the Engineering students inevitably fall into two separate sub-teams that work according to their specific habits with regards to social interaction and task solving. Here, the German students seem more confident with working on concepts and variants on an abstract level than the Korean students, who seem driven to produce more tangible results, like detailed CAD models of chosen components. Again, different levels of experience with the process might account for some of the observed difference, but all participants received the same lecture on the design process at the beginning of the project.

3 IMPLICATIONS ON CROSS-CULTURAL DESIGN THINKING

Even if the observations from teaching practice do not altogether prove that the EDP is less applicable or useful in engineering education in Asia, the authors conclude there is enough cause to assume a difference worth discussing. This and the assumption that Nisbett's findings are valid serve as the foundation for a hypothetical argumentation to explain why Asian students seem not to find the EDP useful in actual design projects, or at least less so than Western students.

First, the approach of generalization itself, the claim that all possible design processes are represented by the EDP should seem dubious to the Asian view of the world. As the EDP can never be directly applied, it is knowledge for knowledge's sake and a lot less useful than - for example - detailed instructions to design a two-stage gear box.

Second, the employed strategy of problem solving, *abstraction* and *analysis* might seem a natural approach to a Westerner but unnecessary and possibly even naïve to the Asian, who would favor a more holistic view of both problem and solution. The analytical approach is indeed criticized because focusing on the elements of problem and solution can result in overlooking interdependencies, which often turn out to be crucial. The methodology tries to compensate for that fault by careful consideration of such interdependencies during the stage of morphological recombination of the partial solutions [8]. Third, the *linearity* of the process is inadequate, because it implies that solution principles can only determine embodiment, but the opposite can not be the case. In a holistic view, everything affects everything, so a reverse causality can not be ignored. Finally, *systematic variation and selection* is awkward, because it ultimately means wasting effort and having to face conflicts due to the selection process. Having to face the possibility of working on a fallback solution that might never be used and having to defend it, possibly even against a variant favoured by a superior team member is not an encouraging option for an Asian, even if some Westerners might consider it an interesting challenge.

Concluding, it can be argued that the EDP conflicts some fundamental Asian principles of thought. As the approach itself has proven to be useful, the question has to be answered if there is a way to teach it more convincingly. A cross-cultural teaching concept should make it clear that the EDP is an effective strategy to solve new types of engineering tasks or to identify radically new solutions, but it can be adapted or even abandoned if the design task requires it. A possible approach could be to complement the problem-oriented EDP with a solution-oriented strategy [10] illustrated in a similar fashion. Figure 2 shows a suggestion for such a process model by the authors. Offering two contrasting strategies, one highly abstracting and analytical and the other completely intuitive and holistic, invites to choose the adequate according to the nature of the task or project situation, or to find a "Middle Way".

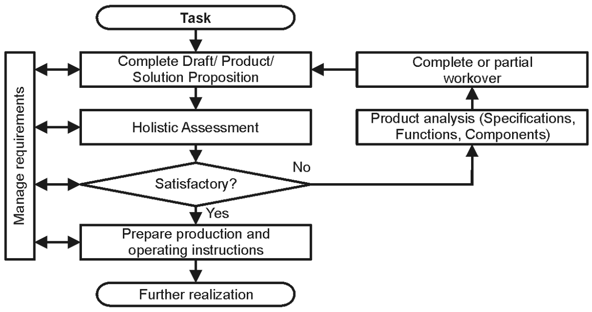

Figure 2. Solution-oriented Design Process

4 CONCLUSION AND OUTLOOK

The growing demand of design-related content in higher education programs in Eastern Asia has established a tradition of Western Design Methodology in Asian Design and Engineering programs. Teaching experience indicates that some of these models might not be as useful in Asia as they have proven to be in Western cultural areas. Using scientific evidence that indeed two profoundly different traditions of thought exist between the Asian and Western cultural spheres, a hypothesis has been formulated that states that the established model of the "Engineering Design Process" contradicts some fundamental Asian principles of thought, which ultimately questions its use in Asian educational programs.

This paper offers ways into improving this state. One strategy could be to include the outlined reasoning, which mainly covers cultural aspects, into design education, to create a clearer understanding of the thinking principles and their benefit for product innovation. Considering the growing importance of intercultural understanding in a globalized world, this approach should be reasonable even without its immediate use for Product Development. A second approach could be to complement the existing methodology itself. In any case, the field of cultural implications on Design Theory calls for empirical research to back up or reject the conclusions drawn in this paper.

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