

TOWARDS A SCIENCE OF DESIGN AS A BASIS OF EDUCATION

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ABSTRACT

Design is defined in the paper in the most general way as a system of activities, which transform the perception of a need into the knowledge required to make or implement an artifact, process or system to satisfy the need. It is argued from this definition that design is an activity basic to all human culture principles of design should be inculcated to all at all stages and levels of education. It indicates the main areas where the development of these principles is being undertaken and the main lines of advance. The paper advocates the development on the basis of these principles of a design science that is general, comprehensive and coherent. It presents an outline of the nature of such a science and of the gaps in our knowledge and understanding, which require research. Finally it presents opinions about the delivery of education in such a science. The paper states in conclusion that the views presented in it are offered for debate.

Keywords: Design science, design education, higher education

1 INTRODUCTION

Everything in the world around us that is not raw nature is the product of technology, where technology is defined as the application of the forces and resources of nature for the use and convenience of humans. In general, these products are the result of design. This is commonly recognized. However, although we know that technology shapes our lives, its methods do not have much intellectual prestige.

This is a common feature of many cultures. We can date it to Antiquity. An excellent example of that attitude is given by the Book of Ecclesiasticus 38:24-34, which speaks of craftsmen as maintaining the fabric of the world, but not being heard in public affairs because of a lack of scholarly wisdom. The book was written probably in the second century BCE in Jerusalem. The passage on craftsmen however can be traced to an ancient Egyptian book as old as 2000 BCE.[1] The views are thus ancient and well embedded in our culture. Ancient Greeks, who laid many of the foundations of the modern world-view similarly considered the work of craftsmen as being inferior to theoretical contemplation. The reason for the neglect of the technological approach was that it had been an art passed from master to apprentice and could not be systematically presented or explained. It has been suggested that this preference of literary knowledge over practical skill impeded the development of technology in the past.[2]

Recent times, however, have brought about a significant change. Modern technology products are commonly created by a systematically organized design process. From this there have emerged in recent times some general principles of design, which are broadly applicable in diverse domains of human knowledge and culture.

This paper points towards the development of a design science, based on these principles, as a foundational and integrating discipline of modern thought. It argues that it should be a basic component of all education. The paper neither reviews comprehensively existing knowledge, nor does it report significant innovation. It sets out an agenda.

2 SOURCES FOR A DESIGN SCIENCE

Design may be defined in the most general way as a system of activities, which transform the perception of a need into the knowledge required to make or implement an artefact, process or system to satisfy the need. It follows from such a definition that design is an activity basic to all human culture. Much culture develops by evolution without explicit design activity. Other aspects are the result of the

activity of a single person, who does not explicitly describe the process of creation of the product and is not, in general, aware of it. However, as humanity advances we explicitly seek out needs to satisfy and purposefully plan the means of satisfying them. In other words, we undertake design.

The product of the design may be a mechanical device, a software application, a business organisation a conference, or a written document. Of course, the knowledge domains involved in all those diverse fields are very different. The detailed methodologies of design differ widely. However, when viewed with adequate abstraction and idealization, there are general principles of design that apply in all domains.

It is not possible here to review the present knowledge and understanding of the principles of design. It is proposed only to indicate the main areas where the development of these principles is being undertaken and the main lines of advance. Literature is cited, which gives an introduction to a detailed picture. Where the works of the present author are cited, it is mainly to indicate his work on design, rather than to claim special significance for the reference cited.

The second half of the last century has seen the development of scientific disciplines, which are concerned with the principles of design, or with some of its core aspects.

Firstly, there is the discipline of design studies, which has the establishment of design principles as the main concern. It approaches the understanding of design from comparisons across all domains of application, including engineering and product design, architectural design and planning, computer artifacts and systems design. Some of its most difficult and interesting concerns are with the finding of embodiments of functions and with the psychological and social aspects of design activity.[3-5]

One of the progenitors of design studies is systems science. It is an interdisciplinary field of great generality. It studies complex objects or situations, by considering them as systems composed of interacting parts. Systems science is based on the use of formal models and exploits analogies among diverse systems. Its main objects are generally analytical and explanatory, but it is also concerned with formal methods of systems design. While, it is mainly concerned with complexity, its methodology is widely applicable.[6,7]

Design, almost invariably, requires decisions to be made to select one of a number of competing candidate concepts. Decision theory provides a theoretical framework for rational decision making in design.[8]

In addition to these generalized disciplines, there are developing methodologies of design in specific fields, which have the potential of fruitful generalization.

Engineering design has developed effective methodologies of wide applicability. Advances in engineering design are driven in particular by the increasing capability of computer modeling. [9-11]

Systems engineering is a discipline of the analysis and design of engineering systems. It provides concepts and tools of great generality, but its focus is on large and complex systems.[12]

Control engineering has a methodology of design of great generality and power. It is specifically focused on systems dynamics, but has potential for wide applications.[13]

Software design is a very significant activity in the modern world. It has a methodology based on systems engineering but with its own perspective and approach.[14]

Information systems design has its own methodology. It is highly developed, with significant potential for generalization.[15]

Requirements engineering is an advancing study. It is focused on problems of information technology, but, given the central importance of requirements in all design problems, requirements engineering has a significant contribution to make to a science of design.[16]

There are thus good sources for a science of design of products. However, this presentation contends that design is central to all culture.

In the modern world government, business and social organizations and activities are, to an increasing extent, explicitly designed. Requirements are defined, options generated and decisions are formally taken. Design concepts are thus increasingly applied in all areas of culture.

Operational research is the earliest discipline that is contributing to this development. The application of information technology is driving the wider adoption of systems design methods. [17]

It must be remarked here that the application of this scientific approach to human affairs is highly contentious. Both the usefulness of this approach and its ethical implications are questioned. This presentation cannot debate the issues involved. It must note the objections, but remark that the advance of these methods indicates their wide acceptance.

Two areas of human activity that may be viewed as using design methodology, but are not generally from this perspective, may be cited as examples of the ubiquity and diversity of design. One is medical treatment; the other is the generation of documents.

In the medical treatment of a patient, the clinician obtains data on the state of health of the patient by clinical examination and tests. From this information the clinician determines the treatment. This process of defining the treatment should involve deciding on objectives and determining the utility of different outcomes, generating candidate treatment options, examining the possible outcomes of alternative treatments and deciding on a treatment using an explicit decision process. The clinician thus follows a design paradigm, though few would recognise it.

Finally, we may consider the production of a written document. In principle, it should begin with a consideration of requirements and the definition of evaluation criteria. The generation of the document involves procedures similar to any kind of design, including the subdivision of the task into components, generation of alternative texts of the components, often the reuse of standard texts and the like. Decisions are often made about which of a number of alternative texts to use. Although few documents are produced by such formal and explicit procedures, the design model is widely applicable to the generation of texts.

There are thus many disciplines, both general and specialized concerned with design. They have much commonality. Notwithstanding their significantly different foci of interest and approaches, they form an adequate basis for the development of a general design science.

Advances in information technology are changing the way in which we view design activity and point the way towards the development of an integrated perspective on design.

Knowledge is basic to design activity, both declarative knowledge in the domain of the object being designed and procedural knowledge about design methods. The development of knowledge engineering is providing us with principles for the representation of knowledge, its storage, retrieval and management. The study of artificial intelligence is providing insight into the processes of problem solving and design concept generation.[18,19]

Finally it may be remarked that as the world changes and technology advances the methodology of technologists is beginning to influence intellectual speculation about the world and human culture.

The influential work of the economist Simon who launched the term the Sciences of the Artificial opened the debate on the topic.[20] Less well known is the work of the Polish philosopher Kotarbinski, who developed the study of praxiology, a branch of philosophy concerned with effective action.[21]

There is a rising interest in the philosophy of engineering.[22] All these areas have the principles of design as a major concern.

3 DESIGN IN EDUCATION

Since design is a basic activity of all culture, principles of design should be inculcated to all at all stages and levels of education. This presentation will, however, concern itself with higher education only. This is for two reasons: higher education is where new teachable disciplines are developed and where teachers for all levels are educated.

Our world is changing rapidly: politically, economically and socially. Many barriers have broken down. There is great movement of people, capital, technology and ideas.

Our knowledge is growing rapidly in all fields. Technology is the most obvious area in which there are rapid advances, the other are the life sciences. However, all fields of human knowledge are growing and deepening as a result of organized endeavour. Knowledge is becoming more interconnected. Any aspect of the world we wish to study, or change, requires the application of knowledge from many domains. The rapid rate of change is set to continue and it is not possible to predict the future with confidence and certainty.

It is increasingly realized that higher education is a life-long process. An initial period of higher education, which is aimed to provide basic knowledge, attitude and skills, must be followed, or integrated with, training in application. It must be continually supplemented by learning and personal development as a progressing career makes new demands and as knowledge and the world change. The initial education must provide a base for this personal development. Further it must educate the person not only for employment, but also as a human being and a member of society.

To satisfy these requirements initial higher education is, in all disciplines, becoming focused on general principles and methods of thought. These tend to be abstract and orientated towards analysis, criticism and speculation. This orientation towards analysis and speculation is damaging.

It is proposed here that given the significant role design plays in human culture the principles of design should be a basic components of most disciplines. Design principles could also serve to integrate diverse disciplines.

4 TOWARDS A SCIENCE OF DESIGN

In order to become a basic and integrating component of education and to influence our world view the principles of design must be formed into a science that is general, comprehensive and coherent. These requirements imply a measure of abstraction and formality. The development of such a science is a formidable task, but progress towards it is necessary.

It is proposed to present here, in outline, the main features and components of a possible design science.

Design science should adopt a systems perspective. It should treat the object to be designed holistically, considering the whole of its life-cycle, any super-system into which it is to be incorporated and the environment in which it is to operate.

However simple the task it will generally have to be divided into a system of sub-tasks, so that even for simple tasks the methodology and terminology of systems design is applicable.

Design is initiated by the establishment design requirements. A methodology for this process, derived from requirements engineering and systems engineering must form part of design science.

Design involves regular use of decisions about candidate design concepts. For this reason the concepts and principles of decision theory must be incorporated into the proposed design science.

Hence the design requirements should be, as far as possible, expressed as quantitative criteria against which candidate design concepts are evaluated.

Thus far then the design principles can be adopted, with little development, from scientific principles for which there is wide consensus and for which general applicability is proven.

The main task in the development of a design science is firstly to establish a model of design activity.

It is proposed that the obvious way forward is to model the activity as knowledge processing,

A model of design activity is proposed here as a conceptual framework for understanding and organizing design.

The model of the design is illustrated in Figure 1.

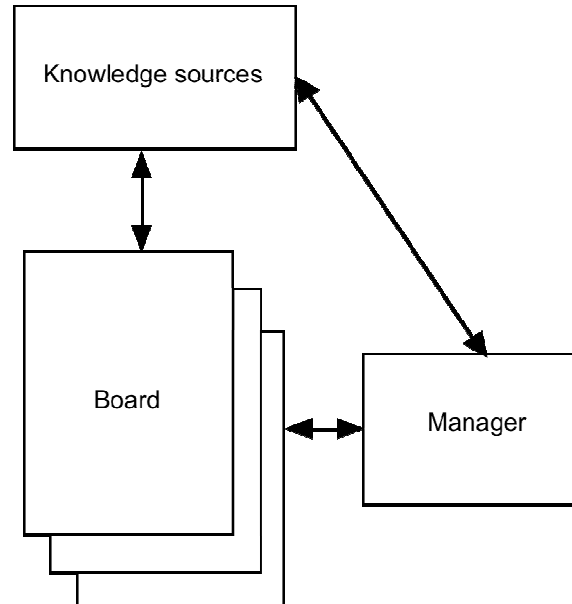


Figure 1. Knowledge based model of the design process

The model consists of knowledge sources, a manager and a central board. These store all the knowledge relevant to the design. This knowledge is of two kinds: declarative and procedural. Declarative knowledge stores all available knowledge relevant to the design task, including previously used design concepts, partial design concepts and the like. The procedural knowledge stores methodology.

The building of declarative knowledge sources for designs in all disciplines is a significant task. It requires development of knowledge representation and organization. The building of procedural knowledge sources requires development of methodology, consisting of the advancement of knowledge of creativity, as well as formalization of presently proven methodologies, such as search of existing catalogues.

A manager, or, designer, controls knowledge source activity, taking decisions on the elements of the design.

The core of the model is a board. The board is a global, structured knowledge base. All solutions generated in the design activity are recorded on the blackboard. They are organized by the board structure according to their levels of abstraction. The model proposed here has different levels of linked boards. They are linked to the different levels of decomposition of the design. The top-level records system solutions, the bottom level records elementary system components, the intermediate levels record sub-systems, sub-sub-systems and like intermediate levels of system decomposition. The model supports top-down, middle-out and bottom-up design. It allows for concurrent design of various parts and aspects of the system. It also allows for reuse of partial solutions and the representation of incremental improvements.

5 TEACHING OF DESIGN SCIENCE

A design science, adequately developed, could form an academic discipline. It could be taught by lectures, supported by design classes. The design classes could take the form of a critical design analysis of products and systems, preparation of a design without implementation, and preferably some design-implement-test studies.

Design science would need to be taught in conjunction with other disciplines, giving it a context. Design science could form a core discipline within a liberal studies curriculum that included other related subjects, such as systems science. In order to be taught and studied such a discipline would need to be taught with examples taken from a wide range of applications.

It is not proposed here to advocate such a curriculum, or to advocate the explicit, autonomous teaching of design studies,

The proposed general abstract design science is proposed as a basic and integrating set of concepts and principles that should be inculcated in most education.

One can divide the disciplines of higher education into two groups: those in which design is, or should be, central to the discipline, for example all engineering and technology. They may be termed design-orientated disciplines. The other group consists of disciplines that do not at present consider design ideas.

Design science should be at the core of design-orientated disciplines. It is outside the scope of this paper to consider specific curricula in detail. However, certain general principles of curriculum design and delivery may be proposed. Design science should be taught from the practical to the theoretical, from the particular to the general and with special consideration of the main discipline. However, the curricula should ensure that they deliver an explicit and comprehensive understanding of design science and be aware of its wide application.

General disciplines should develop the design perspective where applicable.

6 CONCLUSIONS

The paper has put forward a set of views and proposals concerning design.

It argues that design is one of the basic activities of our culture. It further argues that here is much knowledge of the principles of design. It considers that this could and should be organized into an integrated design science of general applicability. The science should be widely taught and studied.

The views and proposals are now opened for discussion and, if thought fit implementation.

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