Design discipline and the significance of visuo-spatial thinking

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This paper discusses the starting points and principles behind two design projects undertaken by students in the Industrial Design Department, Delft University of Technology. The students were included in the design of a hand driven four wheel go-cart and an expresso coffee machine. Preliminary conclusions drawn from the projects were encouraging.

Keywords: Design education, visual thinking, idea-formation

Industrial design partly evolved out of engineering design and the design approach as it developed in arts and crafts teaching. The approach of the latter explains the traditional visual art subjects on the curriculum of industrial design courses. In particular they comprise subjects such as freehand drawings, form studies, as well as representation and modelling techniques, often linked to workshop projects.

Most industrial design courses therefore show the marks of developments that took place in the second part of the nineteenth century and the beginning of the twentieth century in arts and crafts education, influenced among other things by the Arts and Crafts Movement and the Bauhaus.

In this respect the Industrial Design Department at Delft University of Technology does not differ from other courses, with the distinction perhaps that in a predominantly technological environment visual art subjects on a curriculum are at best tolerated. Obviously a certain ability for visual expression is considered indispensable for a designer if he is to take responsibility for the physical shape of a product; visual expression might contribute to the development of certain 'artistic' talents!

The range of visual art subjects on the curriculum at Delft University of Technology is not only limited, the attention given to the object and the importance of these subjects in design education is underestimated if not misjudged to say the least. The ever-increasing complexity of the product development process has understandably led to a wider range of technical subjects in industrial design education, as well as of subjects such as behavioural science and management. As a result visual subjects were reduced in significance. At the the same time, however, this led to a weakening of an important object of these visual subjects, i.e. the development of the three-dimensional cognitive ability inherent in the practice of these subjects, which must be considered indispensable in industrial design education.

In an environment pre-occupied with technical considerations, visual subjects tend to be regarded as peripheral and decorative. The favoured cognitive style is usually verbal-analytical in character. Though the actual design stage is only one phase in the entire product development process, a lack of three-dimensional thinking ability will make itself felt in a negative way as soon as attention is focused on product design in a narrow sense. For at that
moment concrete idea representations will decide to a
great extent the testability of ideas for design solutions.

This overemphasis on verbal-analytical cognition has
been a particular reason for a reassessment of the
significance of visuo-spatial thinking and for the indust-
rial design courses to structure the three-dimensional
thinking process more methodically in order to improve
the realization of designs, and in particular the process of
idea formation and development.

This paper deals with some of the backgrounds of this
specific discipline at Delft University of Technology.
Principles are formulated for design methods and techni-
quies and two projects will be described in order to
illustrate the significance of visuo-spatial thinking.

DESIGN AS A DISCIPLINE IN ITS OWN
RIGHT

What used to be labelled 'industrial design' over the past
decades developed into the comprehensive area of
product development. The emphasis on product design
in a narrow sense shifted to the control of the generation
and subsequent development of products.

Not only technical, but also socio-economic and
industrial-organizational development made it necessary
to view a product in this wider context. Moreover the
label 'industrial design' covered the technical side of
product design so inadequately (supposedly design was
based on aesthetic considerations only), that the design
discipline simply had to be extended to hold its own
among the technical subjects.

To gain some scientific status the subject matter was
broader by attributing equal importance to all kinds of
technical disciplines as well as to ergonomics, psychol-
ogy, methodology, product planning and management;
disciplines that have proved their scientific significance
in the field of theory formulation and research methodol-
gy.

As the discipline Industrial Design lacked (and in
many respects still lacks) exactly this scientific basis,
these coordinated disciplines increasingly dominated the
discipline. As a result the design discipline during the
past decades lost its specific character. When Jochen
Gros tried to formulate what the specific features of
design should be, he concluded that what had started out
as Formgestaltung practically began to belong – by
optimizing the application possibilities – to the field of
anthropometric and informational ergonomics. From
this rather limited approach it was 'transformed' into the
coordination of technical product development, market-
ing and production technology. Thus he correctly
concludes that the discipline Industrial Design in its
development had departed further and further away from
its essence: the definition and determination of the
physical shape of a product.

Of course, in making well considered decisions many
disciplines, often varying according to type of product,
are involved, which are beyond the designer's compe-
tence; this may even be an advantage, because the

essence of his discipline is to integrate the various factors
deciding a product's manufacture and use. Some know-
ledge of technical and behavioural disciplines is indeed
indispensable. However, in all those cases where this
knowledge is insufficient specialist knowledge will have
to be supplied to reach sound design decisions.

To what extent this expertise influences the design is
for the designer to decide. The balancing of all contribut-
ing factors is his true responsibility.

SIDE EFFECTS OF A SCIENTIFIC
APPROACH

The strong scientific bias of industrial design courses, for
which the subdisciplines are especially responsible, has
certainly influenced the discipline favourably. It cannot
be denied that ergonomic studies in product design have
improved the insight into the user's possibilities and/or
limitations. Design-methodological studies in their turn
have made an important contribution to the methodical
structuring of design processes, whilst studies in market-
ing, product planning and management have put into
perspective the part played by product design in product
development.

Strong negative influences are also recognized, espe-
cially where the design discipline itself is concerned.
Apart from the previously mentioned blurring of what is
specific for design discipline, a second, more serious side
effect should be mentioned, i.e. the overemphasis on
analytical thinking in design education, the kind of
thinking inherent in a scientific approach of a discipline
and in scientific research.

Although Michael Tovey claims that ideally the
designer should use a combination of serial-analytical and
holistic-synthetic thinking, we must nevertheless con-
clude that the relation between the two ways of thinking
is out of balance.

Final projects at Delft University of Technology
usually consist of bulky reports with extensive analyses,
documentation of every possible aspect of the problem
and detailed specifications, which with a view to human
comprehension should preferably be put aside if a
synthesis is ever to be reached. The methodological
documentation of the way the project has progressed step
by step is an important, perhaps the most important,
criterion of assessment. A kind of synthesis reached in
this stage seems more important than the content of the
synthesis itself. Not infrequently concrete design propos-
als contrast sharply with the verbal effort made in
methodological justification. Certainly it is the merit of
design methodology that we have come to a better
understanding of the process called designing; it has
supplied us with the instruments to structure some parts
of the process methodically. But where the very essence
of this process manifests itself, even design methodology
must recognize that in its deepest core it is elusive.

Creativity and intuition are attributed to the designer
as important characteristics, but there the matter ends:
hardly any methodically structured insight into the
process of idea formation and idea development is available. This is another reason why attention tends to focus on those parts of the process that can be controlled and verified. As a result design methodology as a description of the process seems to become an aim rather than a means in product design.

A third consequence of an increasingly scientific approach concerns intuitive design decisions. Indeed intuition is seen as an important aid in taking these decisions, but it is inevitably subjective. As subjective design decisions cannot easily be caught in a methodologically verifiable framework, the designer either seeks an 'objective' alibi within that framework, or he flatly denies a subjective framework as a decisive factor (the designer himself!). Apparently intuitive aspects of the environment where a product is going to be used, its appearance, the visual coherence and symbolic aspects etc., cannot or may not be taken into account by the designer.

This wariness of subjectivity could be an impediment to a more holistic approach of a product design situation (at the same time the educational situation). Moreover this attitude seems to take the 'fun' out of designing. In this respect George Baird aptly remarks that 'the very fact that we ourselves are human beings enables us to occupy ourselves with design. But at the same time this condition makes it impossible for us to reach a fully disconnected 'objectivity'. Viewed from that perspective he therefore considers it questionable that many methodologists advocate design methods forcing the designer to assume an uncommitted, objective attitude.

**HOW TO DEAL WITH IDEA REPRESENTATIONS**

The design phase of the product development process can be considered the stage in which verbal starting-points are transformed into an initial physical representation. This tentative definition of solutions requires visuo-spatial thinking expressed in images resulting both from and in representations of a two- and three-dimensional nature. Sketches, drawings and models are indispensable elements in this stage, though as a design-technical means the emphasis is on their effective use in order to generate and develop solutions. A certain ability for the rendering of three-dimensional representation must therefore be seen as an indispensable skill for a designer. This also accounts for the traditional featuring on the curriculum of subjects meant to develop these skills. Sometimes this leads to the supposition that a good artist or draughtsman, as a consequence, is a good designer. Lloyd-Jones' remarks – and rightly so – that this seemingly natural relation should not be taken for granted. For the ability to depict real objects conveys little about the ability to create something entirely new, since drawing is rather reproductive in nature. His plea for a 'contemporary equivalent' of the traditional methods seems to ignore what the ability to rendering images really is: nothing more and nothing less than an ability to express oneself in images, like writing or speaking, is an ability to express oneself in words. This ability is not a design technique, but can be developed as such within structured, controlled proceedings, aimed at stimulating creativity in the interaction between representation and imagination.

At the design course at Delft University of Technology drawing and modelling techniques are used too rarely as a means to structure the process of idea formation and idea development.

The sketches, drawings and models of a project – usually handed in together with bulky reports – are little more than illustrations: static images of a more or less crystallized idea. The representations are hardly, if at all, seen and used as random indications in a developmental sequence. Student attitudes in this respect point in the same direction.

To begin with, the moment at which they have to justify and assess an idea for a certain solution, not only verbally but also visuo-spatially, is postponed as long as possible. On the one hand the student is hampered by his urge to be original: the first visual account of an idea should distinguish itself from the obvious or the banal, and to make it even more complicated, also from that of his fellow students. On the other hand he is convinced – what other possibility is open to him after a thorough analysis of the many data leading to a specification – that more and more information should be made available before he can give a visual image of possible solutions. Both factors characteristic of this procrastination hinder the initiation of synthesis-directed, visual thinking processes; as a result the designer is not able to communicate with his ideas.

If after a long time pen is put to paper, the idea will hardly change during evaluation. A solution is either embraced or rejected on the basis of properties derived from this particular representation. It is striking that the representations are seen as a concrete image of a solution, which cannot be changed – for instance to meet certain criteria in a more satisfactory way – without leading to a completely different solution. The drawing is hardly ever considered representative for a certain type of solution.

![Figure 1. Topological representation of the Flying Dutchman](image-url)
David Pye draws attention to this problem, which is of a general nature. He points out that visual representation has a peculiar aspect: 'Because we visualise particular things and can never visualise anything but what is particular, we fail to realise what an enormous latitude in choice of shapes we normally enjoy.'

This peculiarity too stunts the development of visual thinking processes. This obstacle for that matter can easily be removed by using the representation 'properly'. Initially the idea formation and development process is served by a large quantity and variety of solutions. At first especially the scope of the design is tentatively explored, without any preconceived notions; in that way the different types of solutions will be recognized more easily among the great variety of images. Rober McKim remarks: 'The visual thinker who uses drawing to explore and develop ideas makes many drawings: the idea-finding and idea-formation is not a static one-picture procedure!'

Summarizing it may be said that procrastination in externalizing ideas as well as the rigid attitude towards the first products of the visualizing process prevent the initiation and development of the visuo-spatial thinking process. At the same time they in fact obstruct the stimulation of the creativity that is considered indispensable.

Methods and techniques stimulating the idea formation and idea development process should be defined in such a way that the obstacles mentioned are removed as much as possible. The implementation should initially be characterized by a mainly divergent way of thinking, combined with a spontaneous, impulsive, visuo-spatial response; judgment should be deferred for the time being and as many different techniques as possible should be applied for the representations. A more convergent way of thinking coupled with a mainly reflective response should be reserved for the evaluation stages.

As a matter of fact this last 'attitude' is characteristic for most students at the Delft Design Department. This is mainly due to the way the design process as they get to know it is structured: a step by step sequence of items, a strongly serialized process, implying, in the words of Nigel Cross a serial learning strategy. This attitude does not only characterize Delft students, which may be concluded from Cross's final remark: 'most teachers have a preference for reflective student behaviour!'

STARTING-POINTS FOR IDEA FORMATION AND DEVELOPMENT

Viewed from the perspective of this discussion some members of the Industrial Design Department made an attempt at emphasizing more strongly the development

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**Figure 2. Exploration of typological space**

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of visuo-spatial thinking, particularly the process of idea formation and development. It was considered necessary to give this attitude a more satisfactory status, so that it might be really complementary to the accepted ways of thinking and proposed educational strategies. For this purpose an optional course 'design techniques' for fourth-year students was devised. Studies by Arnhem11, Tjalve12 and McKim13 have contributed to the structure of this optional subject, whose aim is described as: 'the effective use of visual means in order to generate and develop ideas for solutions in the product design process'.

The following starting-points were formulated:

- The different methods and techniques should be used with the end-product in mind, to which is added explicitly that this product is the means of exercising methods and techniques. Both the choice of the product as well as design specifications have been selected deliberately to initiate the idea formation and development process on a visuo-spatial level as early during the design as possible and also to enforce the application of certain methods and techniques for reasons of design strategy.

- The methods and techniques brought to the students' attention are characterized as structured actions both resulting from and resulting in two- and three-dimensional idea representations. The aim is in the first place the stimulation of creativity in the interaction between representation and imagination. The rendering of ideas should therefore mainly serve the communication between designer and design; as the design progresses the presentation character of the drawings will increase.

- Generation of idea representations should especially be aimed at the exploration of the design scope. For design strategy reasons we distinguish two levels:
  - A structural level. Starting-points for immaterial basic elements of product shapes are studied and structural coherence is investigated in relation with product type and product environment (product typological exploration).
    - In practice the variables are manipulated on an overall three-dimensional level. In particular a great variety of topological representations are produced.
  - A formal-material level. The material design scope of the immaterial structural elements are investigated. On the basis of one or more supplied material components, starting points for different form concepts are developed (product morphological exploration).
    - In practice this exploration implies the manipulation of variables on a material level, especially the quantification of different topological structures.
The structure of technique application should remove as many obstacles as possible, by means of detailed instructions for the realization of a project, in order to propel the visual thinking process. To this end a general instruction requires:

- The idea formation should first of all be directed at the generation of a large quantity and diversity of idea representations. In principle judgment is deferred, which will stimulate a way of thought directed at divergence. The student should be urged to react impulsively and to generate idea representations as early as possible (if necessary he should start with the most obvious solutions) so that the visual thinking process is stimulated from the beginning.

- After this initial, preferably time-limited, round of idea formation (after some time fatigue symptoms manifest themselves) the visual material should be evaluated. To solve the problem mentioned by Pye it is of the utmost importance that idea representations are arranged according to type. This can be helpful to gain insight into the real variety of the student's solutions. This insight in its turn can lead to one or more rounds of idea formation, in order to explore the design scope further.

- Evaluation of the different types of solutions leads to a tentative qualitative assessment that results in a preliminary order of merit of the solutions according to their relative promising character. A selection at this point of the most promising solution is as yet deferred.

- Revision of the different solution types aims at an improvement in quality; a combination of certain promising aspects in the solutions will contribute to this. The initial ranking order may thus be rearranged. The way of thought characteristic for these procedures will be rather convergent in nature, the response reflective.

- After these convergent cycles have been gone through some solutions are finally selected and drawn in greater detail.

Seen against the background of these principles a number of projects have been devised for the optional course. To be admitted to the course students were screened. The most important criteria of admission were the ability to express oneself in visual images and the command of a variety of rendering techniques of a both two- and three-dimensional nature. The importance is obvious: if rendering techniques are to be used as design
Figure 5. Global material solutions for different carts

Figure 6. Sketch designs for Flying Dutchman
techniques, the rendering of visual images must not present any problems, while a certain quickness and flexibility in the use of these means are indispensable.

Two of these projects will be discussed here. They were conducted during the first term. Twelve students worked one morning a week, tutored by the author and E.M. Haagsman. The total time devoted to both projects was a hundred hours. All were fourth-year students selected for this course.

An exclusively verbal report on the importance of visual thinking in design would be contradictory to the intentions of this paper. Therefore these projects will be backed up by illustrations.

'THE FLYING DUTCHMAN'

A Flying Dutchman is a four-wheel go-cart driven by handpower. The rider assumes a sitting position, with a lever between his legs. A hinged suspension of the lever in a frame permits a forward translating movement, which is transferred into a rotating movement by means of a crank on the back axle. To steer the cart the rider puts his feet on a hinged front axle. The go-cart is meant to be used by five to eight year olds.

This description can be visualized by a topological illustration as in Figure 1. There are four wheels, arranged in two pairs, a seat and a lever with transmission to the crank axle.

Based on this topological illustration several designs for a Flying Dutchman were made. Visualization methods were introduced with two aims differing in a design-strategical sense: a product typological and a product morphological exploration.

The first exploration implied the generation of images based on the topological starting-point. Variables were: size of wheels, wheelbase, gauge, position and size of seat and lever, as well as the position and relative size of the rider. It was pointed out to the students that different 'values' for these variables on this overall three-dimensional level would yield totally different images. They had to examine to what extent structure characteristics could be detected which were related to different 'semantic' types of carts. A first exploration led to a great number and variety of representations (Figure 2).

A preliminary structure in all this visual material was reached by introducing concept pairs according to which the various images had to be distinguished: quiet-comfortable, fast-sporty, powerful-robust and stylish-elegant. The ordered material was evaluated and the students were asked to record and capture the 'prototypical' images of carts respectively called: easy-rider, sprinter, crosser and trimmer.

This resulted in four prototypical representations in which the basic structural characteristics were visualized (Figure 3). Here the product typological exploration was concluded for the time being.

In the product morphological exploration the topological structure of the vehicle was also the starting-point.
for further evaluation, this time, however, by the introduction of one or more material components. Instead of examining to what extent certain material solutions applied in the basic structure might lead to product characteristics, the students had to connect the topological parts in as many different ways as possible in separate elements: plane material, three-dimensional linear tube and a combination of these. Again a great number and variety of solutions was generated (Figure 4).

The solutions using plane material and three-dimensional tube were meant as 'finger exercises' for the combination of both types of quantification.

Arrangement and evaluation of these images led to a number of feasible solutions, each with its own characteristic features resulting from a particular kind of quantification (Figure 5). Finally these solutions were classified into the categories easy-rider, sprinter, crosser and trimmer as well. Both explorations were mainly divergent in character.

In order to further develop a certain type of vehicle, a synthesis had to be reached of structural characteristics on the one hand and certain material characteristics on the other. From this moment onwards the idea development was of a more convergent nature.

In this stage rough sketches were made of different types of carts (Figure 6). In doing so the technical and ergonomic specifications were applied more strictly, although within the limiting conditions of each type. Finally each student chose one of his four designs for detailed development.

**‘EXPRESSIVE ESPRESSO’**

Because of its specific brewing method and the quality of the coffee, espresso coffee is surrounded with an almost ritualistic atmosphere in Italy and increasingly in Holland as well. Each cup is given its individual treatment. Several operations are necessary to get the equipment going. While the actual brewing is accompanied by ‘noises’ characteristic for this type of coffee making, the espresso ‘brewer’ watches carefully if the frothy layer - the criterion of the perfect brew - is of the right thickness and texture.

Whilst the necessary pressure used to be put on by hand – making coffee in this way was considered an art in Italy – modern equipment is controlled more and more by electromechanical devices. As a result coffee-making is reduced to pressing a button.

This project yielded designs for espresso machines based on the mechanical components (pump, boiler,
Figure 9. Exploration of morphological space

Figure 10. Sketch designs for espresso coffee makers
water-reservoir and electric unit) necessary for this type of coffee making. The starting-point was that emphasis should be given to the ritualistic-culinary aspects of espresso coffee making: expressive espresso!

The 'warming-up' consisted of two parts: to begin with the students had to express visually the notions 'pressing', 'forcing through' and 'extracting'. This first visual brainstorming used free association with all conceivable existing products applying these concepts. Some more or less prototypical drawings were the result (Figure 7). Moreover a ceremonial espresso 'happening' was organized, during which the students could sample the coffee as well as the experience and ambience of the espresso connoisseur.

A more product design-oriented drawing session followed. The students had to formulate different topological principles based on the given components, in order to serve as a structural basis for various types of products. For this purpose the available components were translated into simplified volume units, represented in spatial sketches (foam). Subsequently both two- and three-dimensional combinations were generated. The aim was mainly to produce many varied ways of combination. Any assessment of a preferred combination from a technical and/or production point of view was to be deferred for the time being. With the aid of variables: spatial orientation, position of the elements and the shape of the water-reservoir, a wide range of structures was developed on an overall spatial level, as illustrated in Figure 8.

The functioning of the components in the different combinations formed an important criterion for an evaluation of the ensuing visual material, which led to a reduction of the number of possibilities. The remaining solutions were arranged on a scale varying from 'not very promising' to 'very promising', according to the extent the prototypical characteristics of the first visualization (pressing, forcing through and extracting) had been incorporated.

Further adaptation of the different combinations by means of sketches and three-dimensional models resulted in several fundamental starting-points on a topological level, which could be considered feasible bases for the product types to be developed.

Again a product morphological exploration implied a quantification of the different topological structures. A choice had to be made for a 'casting', using single or double bended plane material. In order to stimulate and control the idea formation at this material level, the different basic structures were used under tracing paper to undergo further adaptation and alteration. Each basic structure yielded a great variety of solutions; as was to be expected the general characteristic of the basic structure greatly influenced the results.

![Figure 11. Models of expressive espresso machines](image-url)
Figure 9 gives an impression of the idea sketches at this stage. Here the principle was rigidly adhered to that all feasible starting-points on a topological level had to be adapted and that no selection whatsoever should be made. This would have limited the divergence of this exploration too drastically. When evaluating the representations in this more concrete phase, the 'expressional quality' was once more the most important criterion, which resulted in a preliminary ranking order.

Taking into account the technical and ergonomic implications and the students' own preference, finally the most promising solution was selected for further development. Within the scope left by the chosen product, detailed form, colour and material research was embarked on, resulting in a sketch design for an espresso machine (Figure 10). The project was rounded off by representations and models (Figure 11), on which a panel of espresso experts was asked to pass judgment.

CONCLUSIONS

Some preliminary conclusions can be drawn from these two projects, which were based on the principles and starting-points described in this paper.

The first is that the stimulation of visuo-spatial thinking processes in design education can be strongly encouraged by structuring these processes in such a way that a dynamic approach to idea representation is stimulated. Whenever this in itself will lead to a more creative product does not seem of the utmost importance, though the chance of arriving at such a product is greatly increased. Never before during three years of design experience had the students produced so much useful visual material!

A second conclusion could be that a phase of idea formation and idea development initially benefits more from an exploration of viewpoints than from an orientation towards the search for a solution. A method directed at this aim generally appears to surprise the students in that it opens their eyes to their own possibilities.

This leads to the third conclusion: the subjective judgment is inevitable when the student is confronted with his own various viewpoints from which a choice has to be made.

A fourth and last conclusion can be drawn from conversations with the students about the experience gained from the described course, compared to the experience previously acquired. A conclusion also of importance to what had been stated in this paper: to improve the educational climate design teachers, insofar as they themselves are designers, should impart more explicitly the knowledge gathered from their own experience. In doing so they can improve the conditions that give wider scope to the creativity of those aspiring to become designers.

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