

CREATING A RESEARCH ENVIRONMENT FOR THE EVALUATION OF DESIGN EDUCATION IN EMBODIMENT DESIGN

C. Spitas, P. Badke-Schaub, V. Spitas, M. Rajabalinejad and E.
Karana

Keywords: design education, methods, evaluation, designer

1. Design education: Where to start from?

Where should design education head for to assure that designers of the future will be able to cope with humans' problems, needs and wishes in an increasing competitive and complex world in an efficient and effective way? Until now, neither the criteria of success such as efficiency and efficacy are clearly defined by the different kinds of 'stakeholders' involved, nor is there an agreement on how to approach the process and ending up with the desired result.

However, this knowledge is needed to develop and implement curricula and arrive at successful design education. Design education in different disciplines has already gone over the years through a variety of changes of the curriculum in order to adapt to requirements of industry, science and politics (see for example the Faculty of Industrial Design Engineering, Delft), which partly were initiated due to European regulations, but there are no systematic evaluation studies delivering empirical data revealing the success of different approaches. This has also been the case in Industrial Design Engineering.

There are approaches of integrating the customer as stakeholder into the design process and this has been established in industrial design education projects in different schools. Research on design education focus mainly on idea generation, based on the prevalence of the inherently creative activity of designing (see for example , human centered design research).

However, the need for supporting designers during different phases of the design process can not be restricted to creativity methods. Moreover, teaching design methodology should not only refer to distinct and flexible methods for information collection, generation, selection and testing of solutions. There should be also an emphasis on ways how to arrive at a meta-level of analysis of own procedures, how to approach and to structure projects. These complex requirements are part of design activities in practice [Badke-Schaub et al. 2011].

Of course, there has been raised valid concerns related to design education with respect to content and methods; however, the question if these criticisms are valid could be only answered by empirical investigations (see also [Margolin 2010], on doctoral education). But there is no established tradition to systematically evaluate design education within elaborated convincing empirical studies.

On the other side, there are the experts of the design research community, who claim that the more or less complete design education as it is now, does not fit with the expectation and the reality of the market. The content and the results of the existing design education and request that design education needs to be changed. Don Norman complains that "today's designers are poorly trained to meet the today's demands." and he requests substantial changes: "We need a new form of design education, one with more rigor, more science, and more attention to the social and behavioral sciences, to modern technology, and to business", [Norman 2010]. According to Norman, design students are not trained to

tackle complex issues, such the interrelated complexities of human and social behavior, or the behavioral sciences, technology, business and science.

While the debate on the best methods to educate designers will in all likelihood continue well into the foreseeable future, it is essential to educate this debate by proposing criteria and appropriate measurement of the effectiveness of design education. Specifically, in this paper we present a theoretically motivated and evaluation-centred research approach which aims to analyse behaviour patterns of students when dealing with complex problems in embodiment design. In the following sections some basic propositions are presented which are seen as determinants for deciding where to start from, what to prioritise and underlying the design activity. Rather than to make claims or generalise the findings to a real design process, we focus on the proposition of a more comprehensive measurement method for the evaluation of design education than what is currently the state of the art. The method is applied on the project course Advanced Products of the Integrated Product Design (IPD) masters curriculum in TU Delft, providing a valuable case study.

2. Design education: What needs to be done?

How can we define ‘effective designing’? How can we transfer this view of effective designing into the teaching process?

Design manifests itself in creation, so creativity must certainly be very relevant.

Can creativity be quantified by the number of ideas produced? Although this is certainly featured as a criterion in different survey results [Spitas 2011a], [Spitas et al. 2012], it does not seem to be the most important metric.

The other main criterion of creativity refers to the novelty of the idea, and at the same time it must be appropriate to solve the problem in question [Finke 1990], [Amabile 1996], [Sternberg 1999]. It is known that all new knowledge is based on existing knowledge. In the same way, new and creative design ideas are firmly embedded in previous information, which is combined, restructured and modified [Hybs and Gero 1992].

Lastly, as creativity can be understood the ability to produce a solution which meets the design requirements, in an optimal way, with the least amount of resources (i.e. time, effort) This picture seems to be strongly supported by literature (see i.e. [Morris 2009], [Rosenthal 1992]) but also by industry, including less scientific professional articles [Lepp 2009].

How can design education transfer the above mentioned criteria of successful designing – of course there are more competencies apart from creativity – to the development and implementation of a design curriculum?

This is exactly where the Integrated Product Design (IPD) master programme for students in the faculty of Industrial Design Engineering (IDE) at TU Delft starts from. The general aim is to support the students in becoming creative problem solvers who are able to deal with complexity and uncertainty in an appropriate way. This appropriateness may entail different factors but we want to mention here creativity as the most important one. We define creativity as the ability to produce non-routine solutions in the context of defining and meeting a goal. Thus creativity is not seen as innate characteristic of the individual but can be taught and trained [Badke-Schaub 2008].

The ‘usual’ curriculum divides the design process into phases moving from an abstract problem definition, typically a design brief, to a concrete product embodiment, typically communicated through a technical data package. In the IPD/IDE curriculum this has been embodied in two distinct phases of ‘concept design’ and ‘embodiment design’. Ultimately, IPD aims to teach and/ or consolidate knowledge and methods for effective design.

3. Designing: Are there essential cognitive mechanisms steering the designer?

Developing educational material needs at least transfer a foundational knowledge about how the wetterwaased on empirical studies of humans’ thinking and acting (see i.e. [Badke-Schaub and Frankenberger 1999], Design Studies, Special Issue; [Birkhofer 2011] and theories on problem solving [Doerner 2004].

The following propositions are set to build the foundational assumptions from which the study has been planned, executed and analysed (see Figure 1).

1. A designer faced with a problem will first identify the characteristics of the given problem and define the problem, before s/he chooses an appropriate method out of the pool of methods.
2. On the basis of the identification of the problem as belonging to a specific type of problems the designer will choose a given design method which addresses this type of problems.
3. This person is sufficiently knowledgeable about the chosen method and accordingly assumes that this type of problem can be solved better by using this method than any other known possible alternative method or sequence of actions.
4. The person is sufficiently competent, knowledgeable and experienced what means s/he is able to use the chosen method in an appropriate way, what also comprises the adaptation of the chosen method to the specific context [Fricke 1996], [Cross 2004]

Of course the quantifiers ‘better’ and ‘sufficiently’ lend themselves to different outcomes that are again person-, method- and context-sensitive.

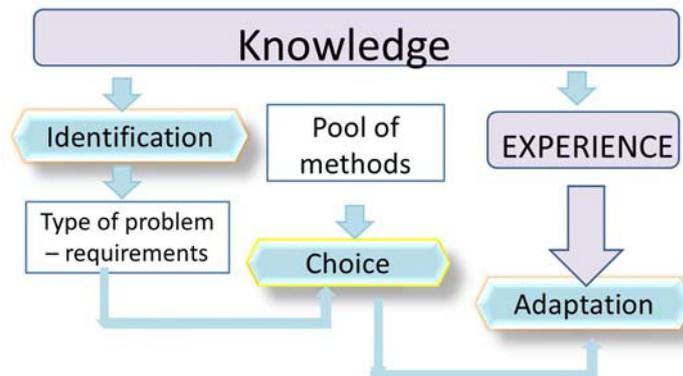


Figure 1. Model of the interrelations of problem identification and choice of methods

Usually design education teaches the students different methods, what means that potentially several methods are available to the (engineering) design students (drawing, calculus, formal logic etc). Some of the methods are taught in different courses during education, either formally or implicitly through example and practice. Thus, the mental model of design methods develops over time and comprise cognitive and behavioural patterns. Regardless of whether or not these working patterns are explicitly/ consciously practiced, they can be considered to comprise methods.

Out of the pool of methods known and available to students, only some are used (more often) and thus transform into consolidated knowledge. In the educational context this usage can be demanded in some cases, in order to make statement (4) true. The use of these methods in design projects provides the students in real-life projects ‘real’ feedback from companies, and thus can be expected to develop an assessment of the effectiveness of methods and thus an opinion about the value of methods (3). In light of proposition (1) we can reasonably expect that, if left to their own devices, students will default to using the methods they consider better and are most comfortable with. We shall call such the students’ default design working patterns.

4. Research set-up

On the basis of the above presented prepositions we define a) our assumptions and accordingly b) the requirements for the research set-up and finally the research questions.

1) Assumptions:

- 1.1) Computational tools foster creativity in learning processes: innovative tools encouraging nonlinear, non-standard thinking and problem-solving, as well as the exploration and generation of new knowledge, ideas and concepts, and thus new associations between existing ideas or concepts. The aim is to support people’s learning as well as the formation and evolution of creative teams by developing technological solutions that facilitate questioning and challenging, foster imaginative thinking, widen the perspectives and make purposeful connections with people and their ideas.
- 1.2) Technology enhanced learning systems endowed with the capabilities of human tutors: Research should advance systems’ capabilities to react to learners’ abilities and difficulties,

and provide systematic feedback based on innovative ways of interpreting the user's responses - particularly in relation to deep/shallow reasoning and thinking. Research should advance systems' understanding and use of the appropriate triggers (praise, constructive comments, etc.) influencing learning. The systems shall improve learners' metacognitive skills, understand and exploit the underlying drivers of their learning behaviours. Solutions should exploit advances in natural language interaction techniques (dialogues), in rich and effective user interfaces and should have a pedagogically sound, smart and personalised instructional design.

2) Requirements for the design of the experiment

- 2.1) We consider that potentially several methods are available to (engineering) design students, Some are learned in different courses during prior education, either formally or implicitly through example and practice, and comprise a host of learned cognitive and behavioural patterns. Regardless of whether or not these working patterns are explicitly/ consciously practiced, they can be considered to comprise methods.
- 2.2) With this insight we proceed with an inventorisation of the research goals that should lead to a cluster of requirements for the design of the experiment.

3) Research questions:

- 3.1) What are the default design working patterns of students in the IPD curriculum, i.e. sequence of actions? Is there a recognisable mean working pattern?
- 3.2) What are the reasons for these working patterns? If there is a recognisable 'mean' working pattern, why is it so?
- 3.3) To what degree do the default design working patterns of students in the IPD curriculum lead to effective design?

While conceiving this research it was expected that carrying it out within the IPD programme would necessitate interaction with several aspects of the curricular structure and related circumstances that could present several constraints as well as opportunities, sometimes at the same time. Thus an inventory of this structure and circumstances was carried out, resulting in the following findings. It is noted that because of the non-linearity and sometimes strong couplings, not all of the pertinent information could be reproduced in the linear discussion that follows.

A practical setting is within the project course 'Advanced Products' (PAP), a 9EC 2nd semester course where students form 20-25 5-person teams (on average), each of which carries out a single real design assignment given by a company for the duration of the semester under the supervision of a coach, approximately once a week, and the course instructor and coordinator at less frequent intervals. *The course does not offer explicit training in design methodology; rather, it is expected and assumed that practice will consolidate a more effective working method.* This project has been running for many years and features validated prototypes among the final deliverables; it is known to give students a sense of responsibility, professionalism, focus on the result and at the same time operational freedom. This setting presents good opportunities for both realism and role-play immersion.

Options identified to perform the experiment were 1) speed design and 2) the full-term project itself. Speed design consists of an intensive assignment that is closely bounded in terms of time, space and inputs. This has obvious benefits for scientific observation. The full term project cannot be reasonably bounded or closely observed, but it can offer insights into how a real project is carried out, in all its depth.

- In service of creating a realistic challenge, the student subjects should experience genuine motivation. Human motives stem from any combination of gratification and hope and it was expected that students have an innate optimism and expectation to be inspired. This sets the framework for all related communications. On the opposite side student passivity, disinterest or cynicism, i.e. due to a feeling of having done 'it' too many times before, should be avoided. Thus a central consideration is catering to the students' requirements: to learn and to make an effort proportional to their learning (i.e. not excessive). This learning must be relevant, tangible and congruent to the overall course style, which requires suitable formulation of the assignment, its wording and the accompanying instructions. In the setting up of this scientific experiment, which does not have education of its subjects as its main goal, and in fact must

not be prescriptive, these requirements create a conflict that can serve both as a threat and an opportunity. One way to fulfil this educational requirement can be by feedback and/ or self-learning/ peer-learning.

- Given the busy study roster, another student requirement is that their workload should be compatible to their time availability, meaning that it should be either a short assignment or embedded in their other regular workflow. A short assignment would be compatible to speed design (snapshot experiment), whereas the regular workflow in the context of the full-term project could be incorporated in a development diary (longitudinal study).
- Other resources include trained staff necessary to supervise the experiment and rooms and equipment required to carry out the design process or to help observe and record it. Students, staff, and equipment should be time-compatible. An opportunity is to deploy the same teams as in-project, simplifying the communication and agenda synchronisation. It remains to be validated whether the PAP team sizes (typically 5 students) are optimal for personal interaction. For logistical reasons, a general goal is to minimise the staff and resource requirements.
- A key requirement of the experimental setup is that it should provide a platform for repeatable observations. This is best done by a controlled environment that can help eliminate external sources of bias, though in the context of this study it has to be balanced with the minimal resource requirement. Primary functions of the setup will be to observe and record. Two different scales of analyse shall be pursued: macro and micro. The macro-scale is concerned with team interaction patterns, whereas the micro-scale with the content and logic of individuals, requiring to ‘zoom in’ on each as appropriate. On both scales it is important to generate protocols and filter/ bookmark relevant information as discrete events that must be clearly identifiable, measurable and where possible quantifiable (i.e. numerical, Boolean, etc). These will admit different types of processing, depending on the focus of a research question, and will have different relevance to different questions. A main task of the research and data post-processing will be to identify these events.

5. Experimental set-up

Driven by the above consideration two snapshot experiments and one longitudinal study with each team in PAP has been run throughout one full semester. 22 teams participated, a total of 110 students. The details and justification of the choices made are as follows.

Snapshot experiments

Two snapshot experiments were held with each student team, one in the beginning of the semester and one near the end. Each experimental run featured one design assignment that the team was expected to complete within one hour. Two assignments were titled ‘adrenaline challenge’ and ‘skateboard challenge’.

The assignments were deliberately simple in phrasing, as follows: 1) ‘Design an installation that produces an adrenaline rush comparable to that of a near death experience and is safe to use’ (adrenaline challenge), 2) ‘Design a skateboard that has at least one unconventional degree of freedom, to increase the fun of skateboarding, and is safe to use’ (skateboard challenge).

It was not known a-priori if the sequence of the assignments would have an influence on the default design working patterns, especially given that teams would be presented with feedback after completing each assignment, so to make such a potential influence measureable the sequence was mixed, with half of the teams executing the ‘adrenaline’ assignment in the first experiment and the ‘skateboard’ assignment in the second one and vice-versa. Students were asked not to discuss their assignment with the other teams between the first and second experiment.

The student teams were given the freedom to arrange by themselves for 1) the time to perform the experiment, 2) a reasonably quiet location that they thought suitable for their design activity and 3) an audio and video recording, by means procured by them. In the end the students were asked to fill-in a debriefing questionnaire. They were also informed that these recordings would be viewed by the course instructor and coordinator, who would then provide them with feedback on their design process. They were informed that participation (not the result) would be awarded a bonus grade.

The format of the snapshot experiment was chosen to provide, as per the above analysis:

- feeling of freedom (default design working patterns),
- (seemingly) completely unfamiliar problem (focus on the process effectiveness rather than the recall of knowledge),
- role-play (avoid educational patterns), concrete reproducible stimulus (written assignment opened on commencing the experiment),
- same student team as in PAP (involvement, familiarity),
- speed design (intensive assignment that is closely bounded in terms of time, space and inputs; suitable for observation),
- opportunity for feedback after each assignment (student motivation and learning, non-biasing as it is after the experiment),
- student effort proportional to learning (short time, no preparation required),
- relevant to PAP context (realistic design),
- minimal resource requirement (students provide location, equipment, self-regulated process according to written instructions),
- observe and record (voice and video).

Some of the requirements are known to have been to some degree compromised, as follows:

- repeatable observations (not possible to reconstruct the team synthesis, or setting, or other contexts; however repeatable assignment and rules),
- external sources of bias (in some cases public collaboration spaces were used, with some noticeable noise; however, no detrimental interactions were observed with the environment),
- ‘zoom in’ on ideas/ content and/ or each individual as appropriate (the generic camera placement did not allow this as a matter of course, except when someone was presenting before the whole team,f;
- in general observation at the micro level and extracting detailed protocols at both macro and micro levels is in some cases difficult).

The effect could not be asserted a-priori. A-posteriori, based on the results, the authors assert that indeed the identified compromises pose limitations to the general applicability of the experimental protocol, as applied, but still the protocol provides sufficient ground for extracting and supporting the main conclusions of this study.

Longitudinal study

This study consisted of a development diary of their actual PAP assignment. The results of this study are not discussed here.

6. Introduction and assessment of benchmark solutions for effectiveness

Referring to the original discussion on the effectiveness of a design process, we recall that a benchmark is needed for any assessment of effectiveness. Both snapshot assignments were designed in such a way as to admit straightforward benchmarks, in the form of simple solutions that can be elaborated sufficiently within the allocated time interval of 1hr. Recalling the exact wording of the assignments, these benchmarks are proposed here as follows:

Adrenaline challenge: It is very straight-forward to induce adrenaline (epinephrine) into the human body directly. Direct injection is an obvious solution which is part of the commonly known state of the art, popularised in mass-media. Safety can be correlated to the adrenaline level in the bloodstream, in consideration of an individual’s constitution and overall health. In any case solutions for monitoring and controlling concentrations of chemicals in the bloodstream are also popularly known. These solutions are obviously part of the benchmark. Qualifying near death experience and how such relates to adrenaline levels in the bloodstream is not so obvious or generally accessible knowledge and researching this correlation can be expected to be the important non-trivial part of the design process.

Skateboard challenge: The structural design, both in terms of principles and embodiments, of conventional skateboards is common and accessible knowledge. What constitutes fun in skateboarding is also immediately accessible and, as games go, can be guaranteed by practically any design. It is also generally known what levels of safety are considered acceptable in skateboarding, where typically the design of the product is not the defining factor for personal safety. The only unexplored/ challenging

feature of the assignment is thus the loose stipulation for ‘strange’ movement. Thus a simple benchmark can be any conventional skateboard with a directly added degree of freedom, by any structural means.

7. Results and discussion

In this analysis the protocols are not yet considered. Instead a bird’s eye view of the processes in the total of over 40hrs of video footage was obtained by firstly reviewing all videos once, singling out interesting patterns like the frequent occurrence of non-trivial/ unexpected patterns, or obvious omissions/ errors, especially with regard to the assignment instructions. In a second review round these patterns were confirmed in a qualitative way. In anticipation of a next phase of post-processing, where detailed protocols are foreseen, no event counts are yet available.

Some striking results are as follows:

- 1) **PRODUCT DEFINITION:** No team arrived at a detailed product definition. This did not seem to be so much a matter of insufficient time, but rather a choice to stay away from actual embodiment. In the feedback round after the first snapshot experiment, all groups were advised to end with a detailed design. However, in the second experiment again no team arrived at a detailed product definition. This may imply a lack of confidence in the design ideas and/or too high uncertainty taking the step to be exposed to real actions including maybe negative feedback.
- 2) **OVERALL PERFORMANCE:** No team achieved a solution comparable in effectiveness to the benchmarks. In the feedback round after the first snapshot experiment, all groups were advised to pursue an effective design process, as defined in this paper. However, in the second experiment again no team arrived at a solution comparable in effectiveness to the benchmarks. This may imply a not sufficiently effective process/ *default design working patterns*. Overall a multitude of design ideas was produced per assignment and team, which can be a confirmation of well-developed imagination and high-affinity to it, but the overwhelming majority of these can be classified as ‘wild ideas’ and as obviously flawed/ ineffective and thus not thought for actual embodiment.
- 3) **TEAM DYNAMICS:** In spite of the written stipulation in the assignment text to question their ideas in the team, ideas were seldom disputed. In particular there were very few instances of processes that could be classified as dialectic, and those were terminated very soon with disagreement shifting to consensus without explicit resolution first. This may suggest that euresis and choice of ideas (Spitas 2011b) seemed to be higher a priority than analysis and evaluation. It may also/ alternatively suggest a lack of training in dialectic as a team process.
- 4) **(LIMITATIONS OF) COGNITION:** Cause-and-effect relationships were in many cases not explicitly discussed and in some cases incorrectly identified (i.e. either no relation or opposite relation). This may have a connection to the noticed absence of dialectic.
- 5) **CLARIFICATION OF TASK:** Design goals were frequently mixed with design solutions, and/ or were in some cases never stated explicitly. In the feedback round after the first snapshot experiment, all groups were advised to take inventory of the keywords in the design brief and derive the design goals from there. This pattern was followed early on in most cases in the second assignment, however the confusion with design solutions still ensued and further goals were invented on the fly, possibly to justify partiality to certain design decisions ad hoc.
- 6) **DECISION MAKING:** In all cases most explicit decisions were taken late in the process, sometimes in the form of a Harris profile to evaluate several design ideas (in the order of 10 per assignment and team) and select one as best. It seems that this is a learned pattern. Erroneously, in many cases requirements were stipulated just before or during this phase, suggesting a late rationalisation process. Typically this activity was followed, in those cases where there was still some time left, by the drawing (not really embodiment, but ‘conceptual detailing’) of the selected idea. In some cases this idea was actually infused with more functionalities and design goals (in the form of add-ons or spin-offs). This divergence may be suggestive of the lack of properly stage-gating the process and/ or of an awareness that the selected idea and/ or the design goals/ criteria are not complete. It may also account for the overall observed inefficiency of the process, as poor ideas were kept longer before evaluating and discarding.

7) **PLANNING THE PROCESS:** In the first experiment planning and time management of the teams was on average poor, with most becoming engaged in cyclic processes of creating ideas but lacking a sense of convergence (students described this as ‘brainstorming’) and resulting in the teams running out of time before finishing. In the feedback round after the first snapshot experiment, all groups were advised to make a plan, commit to it and appoint someone to keep the team on track with this plan (the ‘process keeper’). They were also advised to be convergence-aware and focus on getting the result. There was a noticeable improvement in this aspect in the second experiment; all teams showed a strong commitment to apply this advice and reported satisfaction with their performance in this respect. An issue should be addressed here: Can it be that we are trying to read too much into a 1hr speed design session? In the context of education, as is the setting for this research, it is customary to try to read as much as possible in a short observation (i.e. teachers often rate students, passing or failing them for entire semester-long courses, based on a test of 1-3hrs that produces a much less detailed protocol than what was captured in the present study). Thus this study can only claim that its findings are as representative of the real design process, as any examination result is of the true competence level of the examinee: Valid conclusions can be drawn, but with caution, and generalisations should be avoided. Indeed, with 10-15min available per sub-task, both errors and a general lack of thoroughness are to be expected; however, the authors feel that i.e. designing before defining the requirements, where this was observed, cannot reasonably be attributed to the lack of sufficient time, but instead to a lacking methodological rigour in the default design working pattern (see points 5,6). In fact, the authors claim that a short experiment is better suited to uncover these defaults, exactly because the lack of time affords the subjects little else. At this point we can revisit and attempt to answer the research questions posed during the research set-up (section 4). These are tabulated in Table 1.

Table 1. Analysis of the results, tabulated from discussion items 1-7. Results based on the second snapshot (after feedback)

<i>What are the default design working patterns of students in the IPD curriculum, i.e. sequence of actions? Is there a recognisable mean working pattern?</i>	<i>What are the reasons for these working patterns? If there is a recognisable ‘mean’ working pattern, why is it so?</i>	<i>To what degree do the default design working patterns of students in the IPD curriculum lead to effective design? (speed design only)</i>
1) reluctance to proceed with embodiment	lack of confidence in the design ideas and/ or too high uncertainty?	detailed product definition not reached
2) multitude of design ideas produced	well-developed imagination and high-affinity to it?	undercuts time available, see 1
3) ideas seldom disputed	euresis and choice of ideas higher a priority than analysis and evaluation? lack of training in dialectic as a team process?	delay, see 6
4) cause-and-effect relationships in many cases not explicitly discussed	absence of dialectic?	delay, see 6
5) design goals frequently mixed with design solutions		delay, see 6
6) several design ideas worked out and kept until late; all evaluated at once	lack of properly stage-gating the process and/ or awareness that the selected idea and/ or the design goals/ criteria are not complete?	inefficiency of the process, as poor ideas are kept longer before evaluating and discarding
7) concious time management		

Importantly, we note that, whereas columns 1 and 3 are based on the experimental observations, column 2 is speculative (hence the entries are marked with a question-mark). The authors do not make any claim regarding the validity of these speculations; such verification will be the subject of next experiments.

Also, column 3 can formally be claimed here to be valid only in the speed design context from which the results were obtained. At the same time, though, it has been observed over several years that in the real PAP project, which develops over a comfortable 6 month period, students spend a large part of the time creating and exploring alternative ideas to the point that they are typically late with embodying and prototyping, leaving themselves with little or no time for testing, iterating and improving the design, which is consistent with points 1, 2 and 6.

Overall, some of these findings can be seen as disconcerting. They paint a not-so-flattering image of the competency of students in the middle of an educational curriculum, where things can and must go wrong as an indispensable part of the learning process. Looking at the benchmarks, both the 'adrenaline challenge' and the 'skateboard challenge' were designed to be more illusively simple than they appear which should be enough to throw students off balance. At the same time the authors reflect on the design process as it happens in real industrial settings, which has many times been described by its own practitioners, especially in speed design contexts like this, as 'chaotic'. It is plausible then that what was observed in these snapshot experiments is an accurate snapshot of how off-balance and chaotic are the *default design working patterns* of a designer who lacks the benefit of experience.

If this is true, then it means that the results of this experiment are valid for its context and should not be viewed with shock or distrust but should draw our attention on the problems students of the master course still have one year before they leave the university. In fact these first findings should foster further research in the area of coping with complex design problems in a complex setting.

What does this mean for the PAP course? Comparing the differences between the observations in the first and second snapshots, with the exception of point 7 (time management), it can be concluded that all other identified default working patterns (1-6) did not change significantly. Thus, based on this information, the PAP course cannot be considered as having had an effect on these particular patterns. This is surprising, given that it was implicitly expected that going through a real design project would also consolidate a more effective working method (see section 4). Seeing that PAP is a design course, this research has thus provided valuable results in evaluating and discussing whether affecting such working patterns (i.e. towards better efficiency) should in fact be a learning goal of the course, or if the course should change (perhaps including explicit teaching of design methodology to educate the students' working patterns and change their defaults) to actually meet such a learning goal.

The possibilities and benefits of applying the same method with regard to any design course other than PAP and any design curriculum other than IPD are considered obvious.

8. Conclusions

An experimental method has been proposed for evaluating the effectiveness of design education by assessing students' default design patterns in a speed design context. Application of this method on the design course PAP in the IPD curriculum of the faculty of Industrial Design Engineering in Delft yielded insights as to the students' default design working patterns, the effect of the course on these and ultimately the evaluation of the course itself in connection to its learning objectives. The proposed research environment and experimental method is generalisable to any project-based design curriculum.

Acknowledgements

The authors would like to thank Prof. Frank van der Hoeven for his original proposal of a design assignment to 'design an alternative installation that produces an adrenaline rush based on a near death experience' and the members of the Platform Delft Design and Engineering for their constructive discussions and inspiration. Importantly, the authors are grateful to the PAP students of 2011 who participated in this study.

References

- Amabile, T. M., (1996). "The motivation for creativity in organizations." *Harvard Business Review*, January: 1-4.
- Badke-Schaub, P., Daalhuizen, J., Roozenburg, N., (2011). Towards a designer-centered methodology. In H. Birkhofer (Ed.), *The future of design methodology*. London: Springer, pp. 181-198.
- Badke-Schaub, P., Frankenberger, E., (1999) Analysis of design projects. *Design Studies*, vol. 20, p. 481-494
- Birkhofer (Ed.), *The future of design methodology*. London: Springer.
- Cross, N., (2004) Expertise in design: an overview. *Design studies*, vol. 25, no. 5, p. 427-441
- Daalhuizen, J., Badke-Schaub, P. (2010) the use of methods by advanced beginner and expert industrial designers in non-routine situations: a quasi-experiment. In: by Horváth, I., Mandorli, F. and Rusák, z. (eds.) *Proceedings of the TMCE 2010, April 12–16, 2010, Ancona, Italy*.
- Daalhuizen, J., Badke-Schaub, P., (2011). The use of methods by advanced beginner and expert industrial designers in non-routine situations: a quasi-experiment. *International Journal of Product Development*, vol. 15, no. 1/2/3, p. 54 – 70.
- Doerner, K., Gutjahr, W. J., Hartl, R. F., Strauss, C., Stummer, C., (2004). "Pareto ant colony optimization: A metaheuristic approach to multiobjective portfolio selection." *Annals of Operations Research* 131(1): 79-99.
- Finke, R., "Creative imagery: discoveries and inventions in visualization". Erlbaum Associates, Hillside, N.J., 1990.
- Fricke, G., (1996) *Successful Individual Approaches in Engineering Design*. *Research in engineering design*, vol. 8, p. 151 – 165
- http://core77.com/blog/columns/why_design_education_must_change_17993.asp
- Hybs, I., Gero, J. S., (1992). "An evolutionary process model of design." *Design Studies* 13(3): 273-290.
- Lepp, J., 2009, What is effective design? (in blog: Notes for non-profits), retrieved 11/12/2011 from <http://notesfornonprofits.blogspot.com/2009/03/what-is-effective-design.html>
- Margolin, V., 2010. Doctoral education in design: Problems and Prospects. *Design Issues* 26,3, 70-78.
- Morris, R., 2009, *The fundamentals of product design*, AVA Publishing
- Norman, D., 2010. Why design education must change. *Core*, 10.November, 2010.
- Pahl, G., Beitz, W., (1961). "Engineering design: a systematic approach. 1996." Springer-Verlag, London). *Current research in the engineering design requirement* 387: 31.
- Roozenburg, N., Eekels, J., (1995). *Product design: fundamentals and methods*, Wiley New York.
- Rosenthal, S. R., 1992, *Effective product design and development: How to cut lead time and increase customer satisfaction*, McGraw-Hill
- Spitas, C., 2011, Analysis of systematic engineering design paradigms in industrial practice: A survey, *Journal of Engineering Design*, 22(6), pp. 427-445
- Spitas, C., 2011, Analysis of systematic engineering design paradigms in industrial practice: Scaled experiments, *Journal of Engineering Design*, 22(7), pp. 447-465
- Spitas, C., Spitas, V., Rajabalinejad, M., 2012, *Case studies in advanced engineering design*, Amsterdam, the Netherlands, IOS Press.
- Sternberg, R. J., (1999). *Handbook of creativity*, Cambridge Univ Pr.

Dr. Mohammad Rajabalinejad
Delft University of Technology
Landergstraat 15
2628CE Delft, Netherlands
Telephone: +31620370310
Email: m.rajabalinejad@tudelft.nl