INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'07
28 - 31 AUGUST 2007, CITE DES SCIENCES ET DE L'INDUSTRIE, PARIS, FRANCE

SUCCESS OF A SHAPE CONCEPT AND THE USED MODELLING METHOD

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ABSTRACT
This paper presents a comparison of different shape modelling processes performed during a design contest. Seven design students made a redesign of a phone call logger. Their activities were recorded in photographs, notes and diaries. Apart from sketching, the participants used foam models, clay models and/or CAD. Among the CAD users, some made a physical model by rapid prototyping. After the workshop, the redesigns were evaluated by a panel. Three different evaluation methods were used by the panel: pair wise comparison, indicating the best and the worst concept, and assigning marks to the concepts. It appeared that the success of the concepts did not so much depend on a particular shape ideation method that was used, but rather on the fact whether both physical and digital tools were used or not. Remarkably, the relative appreciation of the individual concept appeared to be different when a different evaluation method was used.

Keywords: Conceptual design, shape ideation, modelling methods

1 INTRODUCTION
Although CAD is widely used to improve the design process, in conceptual design sketching and traditional modelling still play an important role. A survey among product and engineering designers in the Netherlands made clear that 73% of the projects started with some form of sketching or physical clay modelling, although in 93% of the cases a computer-based output was required [1]. Apparently, for conceptual shape design, designers often prefer to start with traditional methods. Current solid modelling and CAD tools are excellent for representing designs at the later stages, but they require a level of effort, certainty and refinement in a design that can make them a poor choice for an early stage prototype [2]. They are not flexible to allow a doodling activity [3]. Brereton has shown, that design thinking is heavily dependent upon references to physical objects and gesturing with physical objects [4]. Similar findings are expressed by Lennings when he writes that shape models "represent the outer appearance of the design, and are meant for visual, tactile and ergonomic evaluation. Important are the advantages of touching, feeling, easily looking from all sides, in one word the 'palpability' of the physical model" [5]. A 3D physical model explains all shape relations in an instant and stimulates and supports designing activities and creativity [6]. Visual and motor representations are highly integrated and action often supports the visual processing [7]. Therefore, the sense of touch is important for embodiment skills, and "the perceptual experience of a physical 3D object is markedly different to the perception of an iconic representation of that object and consequently the manipulation of each requires and develops substantially different skills" [8]. More reasons why many designers still prefer to use non-digital media during conceptualisation are presented by Scali [9]. CAD, however, offers the possibilities of easy storage and retrieval, effortless copying, pasting, rotating, etc. and last but not least a convenient undo function. Although much is written about the use of sketches, models and CAD in conceptual design, data based on actual design processes is scarce, and the effect of the used ideation method on the success of the shape concept is not well known. One of the problems in this area of research is that comparing conceptual design processes is difficult because they are not very well structured, and usually the same product is not designed twice. However, during a design contest, multiple participants design the same type of product under more or less the same circumstances. This

study is based on such a design contest, the Sapporo-Delft design Workshop, which took place August 18-26, 2005, at the Sapporo School of the Art in Sapporo, Japan [10].

2 METHOD

The workshop consisted of a design contest with as participants seven students of the Sapporo School of the Art and of two students of the Delft University of Technology, faculty of Industrial Design Engineering. The participants had to redesign an existing product. The product was 'MyLogger', a computer controlled telephone logger designed for the western market (Figure 1). The goal of the redesign was to adapt the logger to the Japanese market. An industry partner, Jade Ltd., supported the workshop and aimed to elaborate the winning concept and manufacture it. The redesign concerned two concepts, a constrained one and an advanced one. The constrained concept had as a requirement that a manufacturable version could be made in reasonable short time, without the need of designing a new printed circuit board. This restriction did not apply to the advanced concept. The advanced concept, however, should be innovative and add some new value, for example an extra function, easier control or portability.

Figure 1. 'My Logger', the phone call logger that had to be re-designed

The workshop started with an introduction of the organizing partners, i.e. Sapporo School of the Arts, Hokkaido University, Hokkaido Industrial Research Institute, Jade Ltd., Noastec, Will-E and Keio University. After the introduction, the participants could experience the use of the existing logger and ask additional information. After this product analysis, the participants started their ideation. Several tools were available, such as paper, pencils, markers, card board, foam and clay. Computer tools included CAD, CNC milling and STL (stereo lithography). The target group was studied by gathering information about the use and the users of this sort of devices. Collages were made and discussed, requirements were derived, and the sketching of concepts continued. The fourth working day intermediate presentations were given, with the participants and the supervisors as the audience. Each participant had to present three concepts of the constrained model and three concepts of the advanced model. The presentations contained a hand sketch, an oral explanation of how the main requirements were incorporated and a reflection by the supervisors. The participants had to chose which of the three concepts they would elaborate and explain their choice. Again, the supervisors reflected on the presentations.

With the selection of one constrained concept and one advanced concept the second phase of the workshop started. This phase consisted of elaborating the concept by sketching, creating a mock-up and preparing materials for the end presentation. The end presentation was joined by delegates from the involved institutes. Each participant had to deliver a presentation board, a mock-up and an oral explanation. Two types of judgments were made. One consisted of voting by the whole audience, the other was a judgment by the delegates and the supervisors. The workshop ended with the announcement of the winners.

Data was gathered in different ways. The participants were asked to keep a design diary in which they noted each day what they had done, including a photograph of an important sketch or model made that day. Furthermore, each day pictures were taken of all sketches and models that were made. During the presentations, keywords of the oral explanations were noted and pictures of the presented materials were made. Between the two presentations, the participants were interviewed. The gathered data were used to inventory which ideation methods were applied by each individual participant.

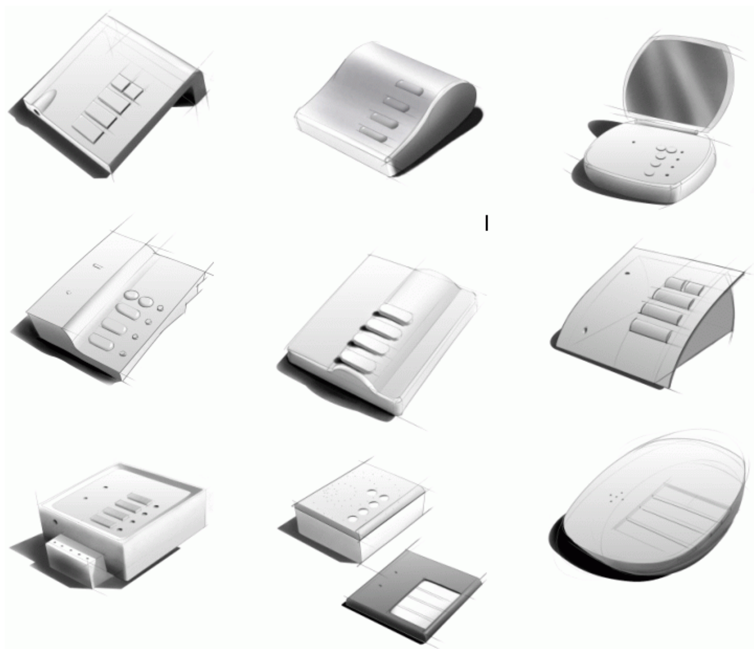

Figure 2.Sketches of the nine concepts

After the workshop, sketches were made of each concept, Figure 2. All sketches were made by the same sketcher, in the same style and with the same level of detail. The sketches were shown to a panel of 27 students of the Faculty of Industrial Design Engineering of the Delft University of Technology, for evaluation of the appearance of the concepts. Three different evaluation methods were used. At first, the sketches were shown pair by pair, and the panel members had to say which one was the best of each pair. During the second evaluation, the panel members had to select the most attractive one and the least attractive concept out of all the sketches. The last evaluation consisted of assigning a mark to each concept and indicating how much the improvement was when compared to the original product. Both marks were expressed as a value on a scale from 0 to 10.

3 RESULTS

This section presents the results. It describes the character of the design process of the designers, and then shows the outcomes of the three tests performed by the panel. After that, the results of the different tests are compared and related to the different types of design process.

3.1 Types of design process

Four subjects made a foam model by hand (S_1, S_6, S_7 and S_9). Two other did the same, but they made a CAD model, too (S_2 and S_3). One subject modelled the concept directly in CAD and retrieved a mock-up by rapid prototyping (S_5). Two subjects used both clay and CAD and applied rapid prototyping to make a mock-up (S_4 and S_8). Besides, all designers made a lot of sketches. Because of this, sketching is not a distinguishing factor in this research and it will not be mentioned in the following part of this paper. Below, the different processes will be indicated with F for foam modelling, FC for foam modelling and CAD, CR for CAD and rapid prototyping (RP) and KCR for clay modelling, CAD and RP. An overview of the process types is shown in Table 1.

Table 1. Types of process used for the different concepts

Process	Used modelling methods	Abbreviation
S_1	Foam modelling, CAD modelling	FC
S_2	Foam modelling, CAD modelling	FC
S_3	Foam modelling, CAD modelling	FC
S_4	Clay modelling, CAD modelling, Rapid Prototyping	KCR
S_5	CAD modelling, Rapid Prototyping	CR
S_6	Foam modelling, CAD modelling	FC
S_7	Foam modelling	F
S_8	Clay modelling, CAD modelling, Rapid Prototyping	KCR
S_9	Foam modelling	F

3.2 Test 1 – Pair wise comparison

The results of the pair wise comparison is presented in Table 2. The table shows for each presented pair the compared concepts, referred to as S_i and S_j. Besides, the number of times S_i was preferred over S_j, indicated as $P_{i,j}$, and the other way around: $P_{j,i}$, the number of times S_j was preferred over S_i. Some information can directly be read from this table. The two extremes are pair 1 and pair 5. In pair 1, with $i = 1$ and $j = 4$, $P_{1,4} = 7$ and $P_{4,1} = 6$, so the number of times S_1 and S_4 are preferred are nearly the same. Pair 5 is the other extreme: $P_{4,5} = 13$ versus $P_{5,4} = 1$, so S_4 is much more popular than S_5.

Table 2. Results of the pair wise comparison
$P_{i,j}$ is the number of times concept i was preferred over concept j

Concept pair	i	j	$P_{i,j}$	$P_{j,i}$
1	1	4	7	6
2	3	4	6	8
3	3	7	9	5
4	3	9	8	6
5	4	5	13	1
6	4	6	11	4
7	4	7	11	3
8	4	9	10	4
9	5	7	4	10
10	5	9	5	8
11	7	8	8	5
12	8	9	10	5

For a more detailed analysis, we calculated for each concept the percentage it was selected as the best one, as follows:
Assume S_a is compared to S_b, S_c, ...
Let P_{ab} be the times S_a was preferred over S_b, and P_{ba} the times S_b was preferred over S_a, then the total number of comparisons between S_a and S_b is $P_{ab} + P_{ba}$, and the percentage of comparisons in which S_a was preferred over S_b is

$$P_{ab} / (P_{ab} + P_{ba}) \quad (1)$$

Finally, the percentage of comparisons in which S_a was preferred over any other S_i is

$$(P_{ab} + P_{ac} + ...) / (P_{ab} + P_{ba} + P_{ac} + P_{ca} + ...) \quad (2)$$

Table 3 shows the results of this expression for all concepts S_i.

Table 3. Results of the pair wise comparison, ordered per concept

i	*j*	% of comparisons in which S_i was preferred over S_j
1	4	53.9
2	-	-
3	4, 7, 9	54.8
4	1, 3, 5, 6, 7, 9	70.2
5	4, 7, 9	25.0
6	4	26.7
7	3, 4, 5, 8	47.3
8	7, 9	53.6
9	3, 4, 5, 8	41.1

The percentage is calculated in the same way for all other concepts, and the outcomes are presented in Figure 2. The highest score is for S_4, followed by S_3, S_1, S_8, S_7, S_9, S_6 and S_5 respectively. Unfortunately, no data is available for S_2.

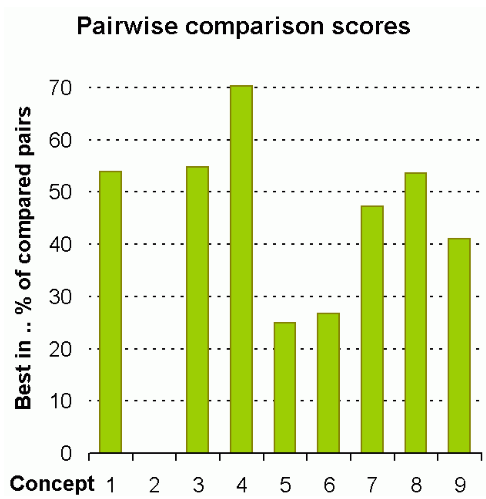

Figure 2. Results of the pair wise comparison by the panel

3.3 Test 2 – Selection of most and least attractive concepts

Table 4 shows how many times each concept was selected as the most attractive one (M_i), and how many times as the least attractive one (L_i). From the table it is clear that the panel members had different tastes, because sometimes the same concept was selected as most attractive by one panel member and as least attractive by another one. This occurs for three concepts (S_2, S_5 and S_7). To compare the concepts, M_i-L_i is calculated and added in the right most column of the table. The highest value is for S_4; and S_5 and S_9 have the lowest value, see Figure 3.

Table 4. Number of times concepts were selected as 'Most Attractive' or 'Least Attractive'

i (Concept)	M_i (nr. of times i was selected as most attractive)	L_i (nr. of times i was selected as least attractive)	M_i-L_i
1	4	-	4
2	1	2	-1
3	4	-	4
4	11	-	11
5	1	11	-10
6	2	-	2
7	3	3	0
8	-	2	-2
9	-	8	-8

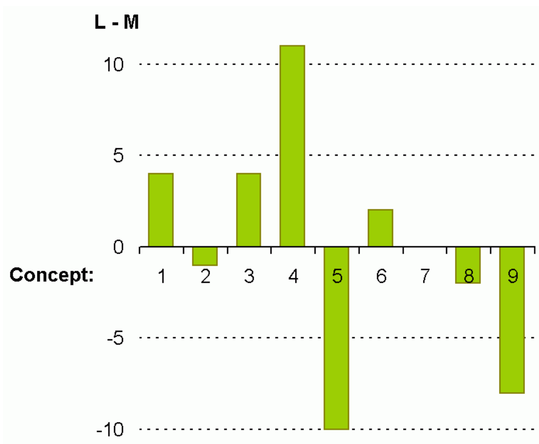

Figure 3. Scores by indicating Most attractive (M_i) and Least attractive (L_i) concepts

3.4 Test 3 – Assigning Marks

In Test 3, two marks were assigned by the panel to each concept. The first mark indicates the panel member's appreciation of the concept. The other mark indicates to which extent the concept is considered as an improvement, compared to the original phone logger. Table 5 shows the averages of the marks, ordered per concept.

Table 5. Assigned marks for Appreciation and Improvement

Concept	Appreciation	Improvement
S_1	6.0	7.3
S_2	5.7	7.0
S_3	6.0	6.3
S_4	5.3	5.7
S_5	5.3	5.7
S_6	6.3	7.7
S_7	5.3	5.0
S_8	3.7	2.7
S_9	4.7	4.7
Average	5.4	5.8

The marks for appreciation range from 3.7 for the concept of S_8 to 6.3 for the concept of S6. It seems the shape of most concepts is not much more appreciated than that of the original phone logger. The marks for improvement show a bit more variety. Their values range from 2.7 for S_8 to 7.7 for S_6. Although the over-all average of improvement is slightly higher than that of appreciation, there is much similarity between both lists. This is even more clear in the graphical presentation in Figure 4.

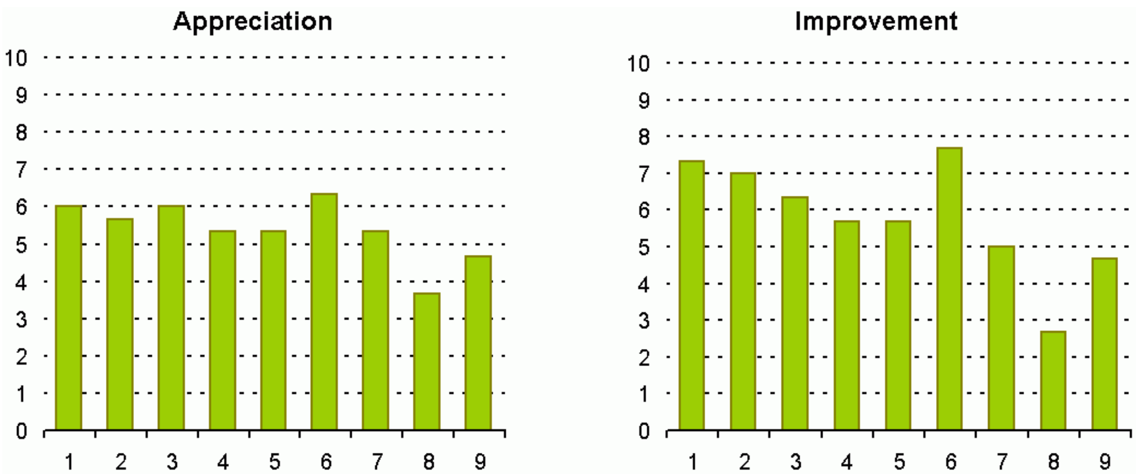

Figure 4. Appreciation and improvement of the concepts, as judged by the panel

Both for appreciation and improvement, S_6 scores best, followed by S_1, S_2 and S_3. Mediocre values occur for S_4, S_5 and S_7, and finally the worst values appear for S_9 and S_8.

3.5 Comparison of the three tests

For easy comparison, the outcomes of all three tests are plotted together in Figure 5. Test 1 and Test 2 show some similarity. Obviously, S_4 has the best value in both tests, followed by S_1 and S_3, with nearly no difference between the latter two. S_5 gets the lowest value. The largest differences between the outcomes of these tests are found for S_6 and S_8 . Where in Test 1 S_8 is in the fourth position and S_6 in place seven, in Test 2 is this just the other way around.

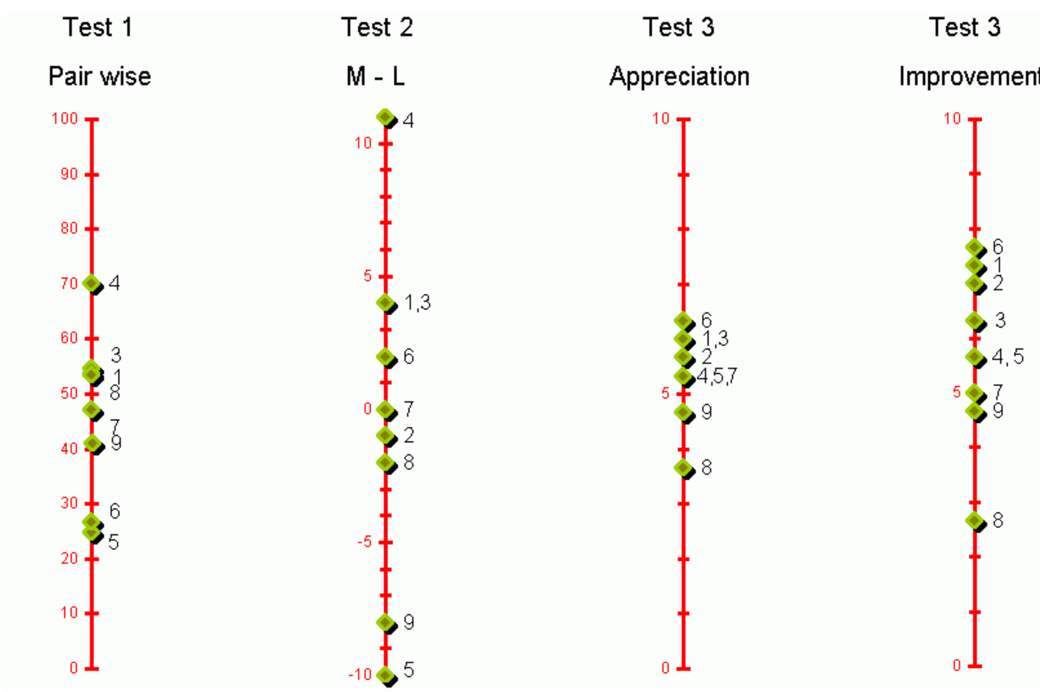

Figure 5. Comparison of the outcomes of the three tests

In Test1 and Test 2, S_4 is at the top, followed by S_1 and S_3. At the bottom we find S_5; S_6, S_7, S_8 and S_9 are in between, and in Test 2 also S_2. The scene is different in Test 3. Here, S_6 is at the top, followed by S_1, S_2 and S_3. We find mediocre values for S_4, S_5 and S_7, a somewhat lower value for S_9 and the lowest value for S_8. Apparently, S_4 is the winner in Test 1 and Test 2, but only mediocre in Test 3, while S_6 wins in Test 3 and is only mediocre in Test 2 and even the one but lowest value in Test 1. Remarkably, the perceived quality of the concepts does not only vary between the different panel members, it also depend on the used research method. However, finding the best concept is not a goal in itself for this research. Rather, we want to know the relation between concept quality and used method. For that, the data will be grouped per process type and discussed in the next section.

3.6 The results ordered per process type

In this section the results are calculated per process type. The concepts for which the same type of process was used, are grouped together. Then it is calculated in how many pair wise comparisons a concept of the group was preferred above a concept from another group, for which another process type was used. The calculation is done with expression (2), just as for the calculation per concept, however, in general, a process type is related to more pair wise comparisons than a concept. The calculated values are presented in Table 6.

Table 6. Number of times concepts of a particular process type were selected as the best, expressed in percent of all selections of that process type

Process	i	j	% of comparisons in which S_i was preferred over S_j
KCR	4, 8	1, 3, 5, 6, 7, 9	66.1
FC	1, 2, 3, 6	4, 7, 9	58.6
CR	5	4, 7, 9	25.0
F	7, 9	3, 4, 5, 8	44.2

Also the data of Test 2 are arranged per process type and recalculated. To calculate M_i, the times a concept was selected as the Most attractive one are summed for all concepts that belong to the same process. L_i is calculated in a similar way. Finally, the difference between M_i and L_i is divided by the number of concepts that belong to the process type, to get the average value. These averages can be found in Table 7. Table 8 shows the marks for Appreciation and for Improvement, from Test 3. These marks are just the average values of the concepts that belong to the same process type.

Table 7. Number of times concepts were selected as 'Most Attractive' or 'Least Attractive'

Process	Concepts	n (Nr. of concepts)	M_i	L_i	$(M_i-L_i)/n$
KCR	S_4, S_8	2	11	2	4.5
FC	S_1, S_2, S_3, S_6	4	11	2	2.3
CR	S_5	1	1	11	-10.0
F	S_7, S_9	2	3	11	-4.0

Table 8. Average marks for Appreciation and Improvement per process type

Process	Concepts	Appreciation	Improvement
KCR	S_4, S_8	11	2
FC	S_1, S_2, S_3, S_6	6.0	7.1
CR	S_5	5.3	5.7
F	S_7, S_9	5.0	4.9

A summary of the results ordered per process type is graphically depicted in Figure 6. When we consider the average values per methods of modelling, the best results of the pair wise comparison are found for the concepts for which CAD and clay was used (KCR). Second best are the ones for which both CAD and manually foam modelling were applied (FC). A lower value is for the concepts that were only modelled in foam (F). Finally, the lowest average is for the models only modelled in CAD (CR). The same order is found for the evaluation by selecting the most attractive and the least attractive concepts, again KCR scores best, followed by FC. However, in this test, F is in the third position, while CR has the lowest score. A different picture appears when the assigned marks are analysed. KCR now appears to get the lowest averages! For the other methods, the order is the same as in Test 2.

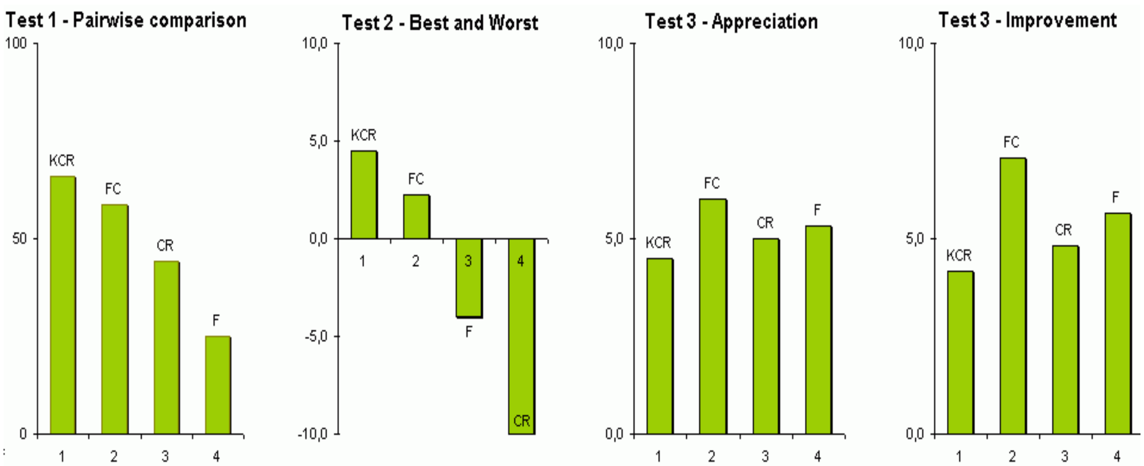

Figure 6. Results of the tests, ordered per process

4 DISCUSSION

Above the scores per concept are shown and the scores per process. However, the number of concepts in this test is low, the data are based on only nine cases. The found values per process are based on four cases for FC, two cases for KCR and F and even only one case for CR. So the values per process are very much influenced by only one case. This can be improved by dividing the concepts in only two groups, in stead of four. One group contains the concepts for which both physical modelling *and* CAD were used: KCR & FC. The other group consists of F & CR, the concepts for which physical modelling *or* CAD was used. The KCR & FC group contains six concepts and the F & CR group contains three ones. Figure 7 shows the results for these two groups. In all graphs, the processes which contain CAD *and* physical modelling score better than those that used a single modelling method.

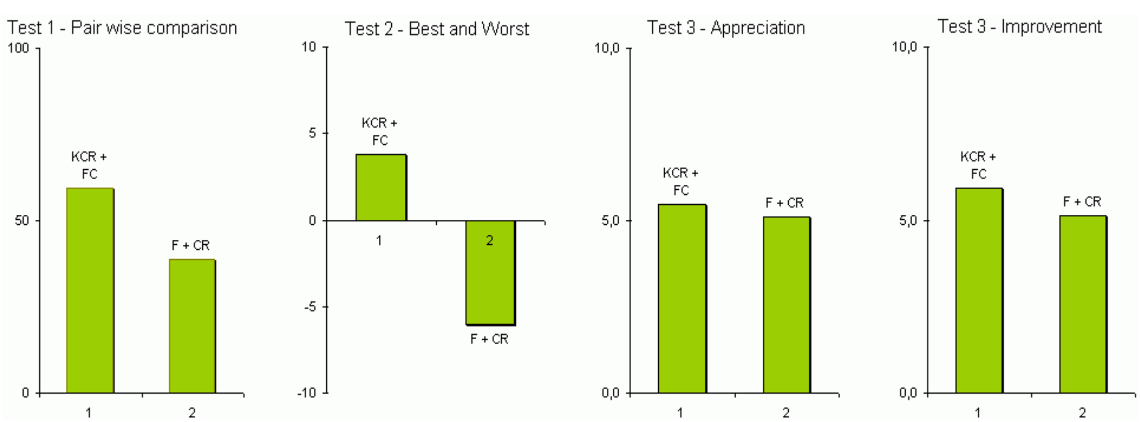

Figure 7. Results for processes with Physical modelling and CAD (KCR & FC) vs. Physical modelling or CAD (F & CR)

5 CONCLUSIONS

The conceptual design processes of nine participants of a design contest were observed. Four different process types were distinguished. The success of the concepts was evaluated by a panel that used three different evaluation methods. From the results we conclude that with the use of different modelling methods, also the average appreciation of the modelled concept was different. However, the processes that contained both physical modelling and CAD appeared to give better results than those that only used physical modelling or CAD. This research has restrictions. Its findings are based on only nine design processes. The outcomes should not be over generalised by stating that using physical and digital modelling always delivers better concepts. Yet the results are interesting and worth to be the subject of further research.

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