FAILURE STRESS AS A MOTIVATOR FOR CREATIVE CONSTRUCTION MANAGEMENT

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Abstract

A building assignment is a complex task that demands collaborative working in order to achieve added value for users and society through creative construction management. Modular building systems are used in workshops in the building environment domain to make students aware of various phenomena that occur in the process of creative construction. Existing modular building systems used in training do not include the experience of failure as a motivator for creative construction. This article validates an innovative set of modular building materials (Handstorm®) that has a high innate risk of construction failure, as a tool in using failure as a motivator in creative construction. It reports on the effect of both innate failures – such as instability or collapsing – and emotional failures, such as the success of a competitor or losing a competition. The results indicate that the presence of failure stress is a valid motivator in teaching creative construction management.

Keywords: collaborative design, creative tools, education, failure stress, modular system

1. INTRODUCTION

Effective learning by experience is well developed and scientifically validated in the curricula of primary education. It stimulates discussion and the sharing of experience, and it encourages pupils to starts researching, which leads to the mastering of new skills and the development of concepts of thought (Laevers, 2000; Verhoeven, 2003). According to Gore (2003), studio teaching of architecture students whereby they obtained direct experience of construction materials, led to the same learning pattern, resulting in critical thinking and actual innovation, with failure of the construction as one of the best motivators. Failure as a motivator in effective design has a long history (Pretoski, 2006), but dependable educational tools to teach design teams this phenomenon are scarce, especially when large numbers of students are involved and studio teaching is the only available option.

Various modular building systems that allow for endless variations have been developed for studio teaching. LEGO® SERIOUS PLAY™ (LEGO) is a building system for teaching innovation of business strategy that is based on the work of Roos et al. (2006). It is a play in which building blocks and their connections are metaphors for communication, cohesion, and social bonding in constructing new organizations that are ready for the unexpected in order to maximize shareholder value. Success and co-ownership of the problem are the main motivators, not failure. This is also the case in the Lean Apartment Construction Game (LEAPCOM) (Sacks 2005), in which the aim is to construct an 8-story building with 4 apartments on each floor, each customized to the specific design specifications of individual home owners (ibid.). The conflicts that arise have to be solved and waste must be reduced. Collaboration among the partners in the building process is the subject taught, not the effect of failure stress.

In the context of this research, “failure is an unacceptable difference between expected and observed performance” (Carper, 1996). This difference can cause stress, and if the stress is not too low or not too high, the performances can be optimal (Seyle, 1978). The failure stress is then a motivator or a provocative stimulus. “Such stimuli are intended to provoke designers to consider various trains of thought that they might not otherwise think about” (Smith, 2006).

“Planned” failure intended to provide direct experience of team designing seems to ask for a different set of modular building materials. The aim of this report is to validate an innovative set of modular building materials as an educational tool in using failure as a useful motivator in teaching collaborative design.

2. THE TOOL AND ITS USE

The first author developed the Handstorm® Modular Building System (MBS), which has a high innate rate of building failure induction. The MBS consists of (see Figure 1A):

- 10 plywood disks, 600 mm in diameter, with 8 x 25 mm holes near the outer rim.
- 80 pine wood poles, 600 mm long, 22 mm in diameter, with 5 x 10 mm holes.
- 200 sticks, 600 mm long, 9 mm in diameter.
- 200 sticks, 100 mm long, 9 mm in diameter.

Upon inspection, it seems obvious that the poles have to go into the holes in the disk in order to build platforms of one or more stories high. The loose fitting of the poles in the holes, and the fact that the holes are placed in a large circle, causes the structure to fail as soon as it is loaded with some extra weight (Figure 1B). Stability and strength are improved by placing some of the thinner sticks in some of the pole holes (Figure 1C). Since these fittings are also rather loose, some thought has to be given to the direction and positioning of the sticks.

3. VALIDATION METHODOLOGY

Although the Handstorm® MBS is mainly meant for graduate and postgraduate teaching (Cases A & D), we decided also to use experimental groups of primary school children (Cases B & C) to find the limits of the educational application of the system. In all cases, a reward followed the completion of the task. The winning group of students earned a bottle of wine, while the losing group were given a bottle of lemonade. The winning group of school children were photographed on top of the completed platform. They could download their picture from the internet the next day.

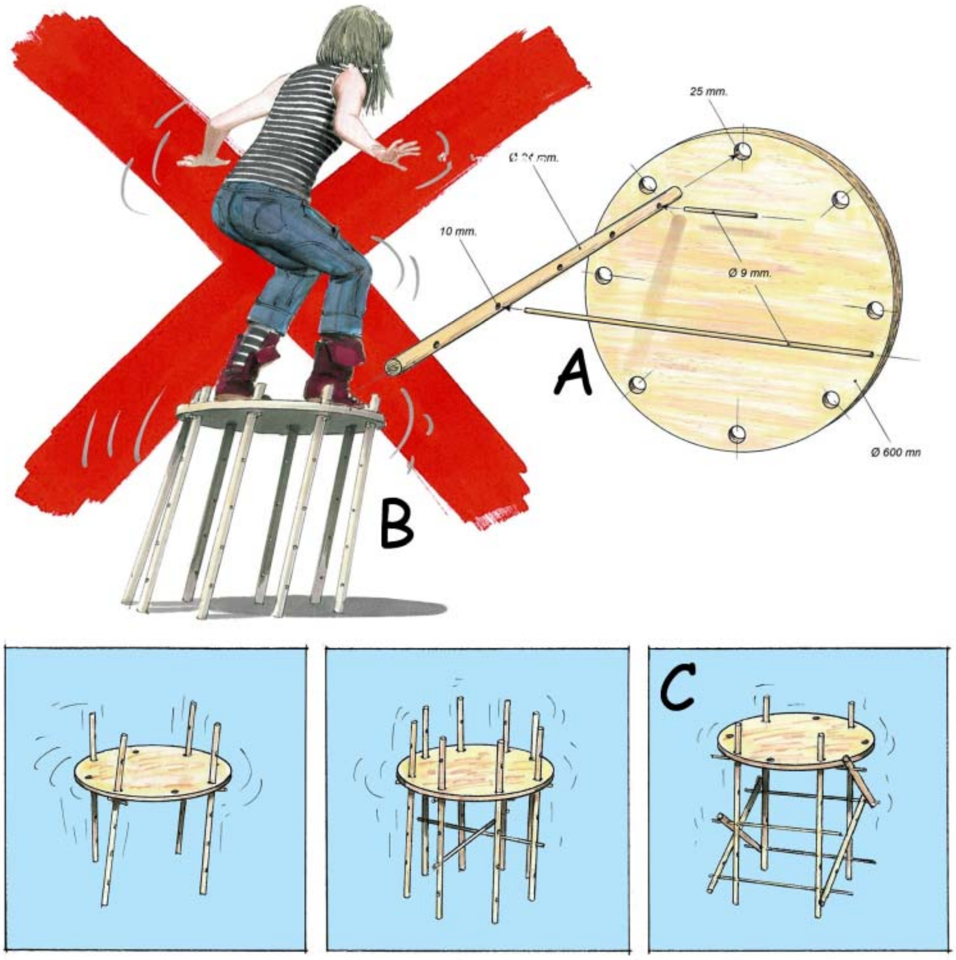

Figure 1: (A) Handstorm® Modular Building System parts; (B) Failure of the simple construction of disk and poles and (C) Remedying this by thoughtfully positioning a few connecting sticks.

The design and building process was monitored either by the first author (Cases A, B, & D) or by both the first and the second author (Case C). The process was either documented on video (Cases A, B, & D) or photographed (Case C). In all cases, only one video camera was used. In cases A and B, the first author recorded only the interesting activities of a group. In addition to preparing a written qualitative summary of the design and building process, the video recordings were analyzed quantitatively. The recording was broken up into 30-minute blocks, and the blocks were categorized and scored according to the following classes of activity: no activity, discussion, trying the connections of the MBS, construction according to initial design, improving the construction, testing the construction, and construction according to a new design (Table 1). The design activity that resulted from a failure was also explored (Table 2). Two types of failings were defined: innate failing (instability caused by moving or loading, and collapsing upon loading) and emotional failing (observing the success of the other group or losing the competition).

Case A: Postgraduates in competition

Participants: Two groups of 5 or 6 novice designers (3 females & 2 males, and 2 females & 4 males, respectively; aged 23–25 years). All had a MSc: four in Architecture (but no practical experience in the profession), one in Landscape Architecture, one in Innovation Management, one in Psychology, and four in Urban Design.

Situation: On October 26, 2004, an MBS assignment was organized as a competition between the two groups at the end of a class on the management of innovation processes in design groups, which is part of the postgraduate Architectural Design Management Systems program at Eindhoven University of Technology. No specific guidance was given, and no examples of structures were shown.

The design students were allowed 60 minutes to design and construct a platform that had to be as high as possible, incorporate the smallest number of building parts as possible, and be able to carry the weight of all members of the group at the same time (one person on each disk). The groups worked in the same room and could observe each other.

Case B: Primary school children at the university's open day

Participants: Mostly primary school children (50% males, 50% females, aged 6–14 years) and their parents at Eindhoven University of Technology's open day on October 3, 2004. The open day is an annual event that is heavily advertised beforehand. The Department of Architecture, Building and Planning organized the MBS event to show children both the constructional and the architectural side of its domain.

Situation: We asked the children to build a nice looking Idols™ platform that could bear the weight of one child. For this, 10 working stations were set up in a large hallway. Each working station was manned from 12:00 to 17:00 by an undergraduate Architecture student, whose job was to ensure the children's safety and security, and to take photographs after the task had been completed. The public, including other children, could freely walk in and out the hallway and from one working station to another. Only one group was allowed at each working station, but there was no time limit for task completion. Groups could have any size, and some were very large. In addition to the MBS, some extra materials were provided so that the children could beautify their platform, namely: sheets of colored cardboard, a pair of scissors, and drawing materials; sticks 1200 mm long to support the cardboard; and additional connecting materials (rope, rubber bands, paperclips and adhesive tape). A finished example was present for instruction and introduction purposes, as was a written description of the task (mainly for parents). Several colored posters advertising the task were hung on walls inside and outside the hallway. No oral guidance was given to the children, unless it was necessary to ensure their safety. In total, 81 platforms were completed. Two building trials were recorded on video and analyzed. Group I consisted of 3 boys aged 11–14 years, and Group II of 3 boys of about 10 years and 1 girl of 6 years.

Case C: Primary school children in a compulsory event

Participants: Thirteen primary school children (6 males, 7 females, aged 9–11 years) and their teachers at the AVS (association of school directors) conference in Nieuwegein, the Netherlands, during school hours on April 27, 2006.

Situation: The assignment and setup were similar to Case B, but only three working stations were supplied in a large room, where the platform building had to compete with nine other interesting technology activities. Paper clamps and textile sheets were added to the materials mentioned for Case B as additional beautifying and connecting supports. Pictures of completed platforms were shown. The children were instructed orally in aspects of strength and stability by the first author through the construction of three example platforms with increasing levels of stability and strength. The children were not allowed to leave the room during the event. Groups formed voluntarily. Four of these groups finished the assignment within an hour. At this event, MBS received second prize in the national innovation competition for primary education in technology (Kader Primair, 2006).

Case D: Graduates in competition

Participants: Two groups of six design students at Master's level (all males, aged 22–23 years) with Bachelor degrees in Civil Engineering and Architecture.

Situation: On October 17, 2006 an MBS assignment was organized as a competition between the two groups during a class that forms part of Eindhoven University of Technology's Construction Management and Engineering program. Each group was observed by three students. The assignment was the same as in Case A.

4. VALIDATION RESULTS

Postgraduates

Process: **Group I** first examined the building materials. No group leader came forward. The group started by making calculations to find out the best chance of winning with the supplied materials: greater height or fewer building parts.

After 35 minutes, the group completed building and tested the construction. The structure failed (Figure 2). The reactions of the group members to the collapse ranged from laughing, looking helplessly at the spectators, examining the (broken) MBS parts, and asking the lecturer whether the collapse was a normal part of this methodology, and why these tools were not more robust. However, immediately after the collapse, the group started to construct a completely different platform. This happened without much discussion among the group members. It seems as though their hands automatically knew what they should do. In just three minutes, the concept of a new platform was born; three minutes later, the platform passed the loading test (Figure 3). The group spent the remaining 10 minutes optimizing the construction by reducing the number of building parts without losing stability or strength.

Figure 2: The novice designers in Group I test their platform. It collapses, causing much hilarity among the group members, and leads to a new design

In **Group II,** an informal leader stood up within 30 seconds, and proceeded to introduce the flip-over board to tackle the design problem. During the whole session, this tool remained in use for a cumulative period of 4.5 minutes. The informal leader started to explain the design strategy to the lecturer 8 minutes later: the group had decided to use the long sticks as much as possible, to support a structure with 3 higher and 3 lower disks, and to use a pole for one extra disk. As soon as Group II saw that Group I had succeeded with another type of platform, they stood there abashed. They dismantled their own structure within 2 minutes, and within another 7 minutes they had built another one that could support the required weight (Figure 3). Since their structure was lower and contained more building parts, they were declared the losers. Eight minutes after the competition, two members of Group II realized a completely new concept using the group members as structural elements, thus increasing the height without using any extra wooden building parts (Figure 3).

Figure 3: Both Group I and Group II pass the weight test. Group I was the winner (A), Group II the loser (B)

Effect of failure: In **Group I,** the crisis caused by the collapse of the platform resulted in the prompt discard of the initial design concept, and the quick development, adoption, and execution of an innovative and better design.

In the case of **Group II,** the failure came from outside sources: First, from Group I (which they considered a sure winner), and second (after the competition), through the shocking event of having lost mercilessly.

Children at the open day

Process: **Group I** succeeded in building a weight-carrying platform within 11 minutes. However, one of the boys immediately criticized their own design by saying "It looks terrible!" The group members were also not satisfied with the stability and continued to add sticks to the structure until the wobbling ceased completely (Figure 4). During the whole building process, the group members kept up a lively discussion.

In the case of **Group II,** the boys did the building, while the girl worked on the decoration of the platform. There was no connection between the boys and the girl. The construction was dominated by a boy who whistled frequently, scolded the other boys, indicated that this or that did not work, pulled on sticks and poles, went away, came back again, and gesticulated a lot when things did not go his way. Wobbling during testing was tackled with rope and elastic bands (Figure 4).

Effect of failure: In both cases, the wobbling of the construction, when observed, led only to the addition of more building or connecting materials, and not to a fundamental change in design.

Figure 4: The Idols™ platforms of the two groups

Figure 5: An Idols™ platform under construction and one completed at the AVS conference

Children at the compulsory event

Process: The MBS working stations did not attract sufficient attention, and the first two authors had to actively motivate children to start and complete the construction assignment. The other nine activities in the room were more rewarding for most children. One group that completed the platform, covered it completely with colored cloth before the photograph was taken. The children really experienced themselves as Idols™ (Figure 5).

Effect of failure: None; the attendants solved all the problems that arose.

Graduates

Process: **Group I** spent the first 10 minutes discussing the assignment and designing some solutions with the help of a flip-over board. By constructing the initial design, the group realized that a simple MBS platform is not stabile by itself. They dismantled it and started to construct a new one. This happened 3 times within 10 minutes. The group constantly tested the construction for stability by loading it. The fourth attempt succeeded, and they decided to optimize the construction. Two shorts sticks were replaced by one long stick.

The group finished the assignment within the time limit. The observers noted that the graduates did not organize the process and did not spend much time analyzing the problem. One of the observers told the lecturer: “If I were a member of the group, I’d have done the same.” When the assignment was finished, the group found time to reflect on the strategy: A smaller number of parts is more important than the height attained. Everybody in the group was involved in the process.

Group II also spent 10 minutes discussing a solution; they used a note pad and did not really collaborate. They worked for about 15 minutes, and during that time they hardly tested for stability. After that, they decided to dismantle the construction, probably influenced by the results of Group I. Their second try succeeded after 20 minutes, and they decided to optimize the construction by placing another disk on top. This caused a lot of stability problems that were not solved within the 60-minute time limit. When the construction was subsequently tested, it collapsed. The observers reported that the group members designed individually and did not share their ideas or collaborate. The design arose not through discussion, but by trial and error.

Before the competition started, the students explained why they had chosen the Master's program in Construction Management and Engineering. Most of them had been attracted by organizing and managing the whole construction process. The building experience confronted them with the meaning of such management. As the observers commented, they had hardly organized or managed the process. This recognition startled them.

Effect of failure: In **Group I**, instability led to four designs. **Group II** felt that the other group was more successful, and thus started a new design. For one reason or another, the group did not test their work within the given time. Were they afraid that the construction would collapse?

Group I was proud to win the bottle of wine, but **Group II** was not amused – and returned the bottle of lemonade.

Quantitative analysis

The four design groups of graduate/postgraduate students had lengthy discussions to attain consensus on a design concept before they started to build. They sometimes stopped, perhaps to think things over. The groups of children simply started and did not stop building until they had finished. Children tested their structure when they thought it was ready, and simply added more building and connecting materials if the platform wobbled or threatened to collapse. The student groups reacted differently to the threat of a failure: They adopted new, and sometimes innovative, designs (Tables 1 and 2).

Table 1: Frequency of activities (30-minute blocks in the video recording) during design and building with Handstorm® Modular Building System in groups of postgraduate design students (A), primary school children (B), and graduates (D). In Cases A and B, only the interesting 30-minute blocks were recorded at the discretion of the first author.

Activity	**Frequency in %**					
	A_I	**A_{II}**	**B_I**	**B_{II}**	**D_I**	**D_{II}**
No activity	2	2	0	0	23	4
Discussion	17	20	0	4	24	23
Trying connections	4	5	0	0	3	5
Constructing initial design	11	27	44	29	3	17

Improving the construction	5	0	0	13	8	11
Testing the construction	11	3	5	11	9	7
Construction to new design	13	7	0	0	28	32
Not recorded 30-minute blocks	37	36	51	43	3	3
Total no. of 30-minute blocks	103	101	61	56	119	120
Total duration of the experiment	51’30’’	50’30’’	30’30’’	28’	59’30”	60’

5. DISCUSSION

The teaching objective of experiencing both innate and emotional failure as a motivator for innovative design was met by the graduates and postgraduates, but not by the primary school children. It is obvious that the absence of a problem analysis stage in the case of the children designers (they simply discussed matters), is related to their developmental stage (Piaget, 2006). An external motivator, such as the aim of winning, is needed as a starter, with internal (innate) failure stress as a sustainer.

Table 2: Responsive activities after perceived failures

Group	Failure description	Responsive activity	N
$\mathbf{A_{I}}$	Collapse upon loading	Constructing to new design	1
	Losing the competition	Improving the construction	1
$\mathbf{A_{II}}$	Observing success other group	Constructing to new design	2
	Observing success other group	Constructing to new design *	
$\mathbf{B_{I}}$	Instability	Improving	1
$\mathbf{B_{II}}$	Instability	Improving	1
$\mathbf{D_{I}}$	Instability	Constructing to new design	4
	Instability	Constructing to new design	
	Instability	Constructing to new design	
	Instability	Constructing to new design	
	Losing the competition	Improving the construction	1
$\mathbf{D_{II}}$	Observing success other group	Constructing to new design	1
	Instability	Improving the construction	1
	Losing the competition	Improving the construction	1
	Collapse upon loading *	No activity	

The absence of failure stress, however, is most likely caused by another mechanism. The children had only one innate failing risk to attend to: a collapsing platform. Enough spare building and connecting parts were available to surmount any instability of the platform, and there was no competition with other groups. The university students, however, faced a much more complex task. Requirements such as reducing the number of building parts and constructing higher, are conflicting. Choices had to be made, and the wrong one would lead to the collapse of the platform or to losing the competition. The introduction of complexity through conflicting requirements and the objective to win a competition turns the Handstorm® MBS into a dependable and “real world” teaching tool.

The question remains why this effect is not readily obtained with other MBS used in teaching, such as LEGO® SERIOUS PLAY™, [4] which also involve competing requirements. Design teams in architecture and building are, however, project organizations with a short life time that ends upon the completion of the designing project, while teams of managers who develop business strategies are expected to execute their own strategic plans for years to come. Therefore, in teaching business innovation, the focus is not on the innovation as such, but on building a sustainable team. Learning through failure could damage cohesion and social bonding in the long run, or might demotivate group members from tackling the task at hand.

For the project organization of design teams, the Handstorm® MBS elicited collaborative design driven by failure stress in novice designers who had to cope with a number of partially conflicting requirements. Primary school children, who only had to cope with the shocking event of the collapse of their platforms, did not show such innovative behavior. The children followed the optimizing path in the design and construction process. We conclude that MBS that have a high innate risk of structural collapse, such as the Handstorm® MBS, are tools for teaching design teams the value of failure stress in design, in order to prevent failures in the final construction of real-life building projects. This brings Gore's (2003) "serious play" to the teaching studio, and we agree with Gore that these lessons "stick" and are transferable.

6. CONCLUSIONS

As an educational tool, the Handstorm® MBS is a valid motivator for the use of failures in collaborative design. It makes the student more aware that failures help the team to construct according to newly developed designs. When the stress of the failure is too low or too high, it kills motivation.

The lessons derived from the cases will lead to the further development of the Handstorm® MBS in order to make it suitable for extensive implementation. We will consider different shaped disks, more holes in the parts, coloring the parts, etc., so as to increase the number of possible types of assignments.

At a higher level, we believe that the concept of failure is a tool to break designers out of their established pattern during collaborative design meetings. It fits all kinds of problem solving and creativity thinking techniques.

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