A Pedagogical Game based on Lego Bricks for Collaborative Design Practices Analysis

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Abstract. In this paper we present a pedagogical game intended to simulate the collaborative design activities of mechanical products as part of the formation programme for future engineers. This game is based on the adaptation of the Delta Design game developed at M.I.T. The principle of the game is to co-imagine a space shuttle built in Lego® blocks with functions and rules assigned for several students. The software used (MLCad) provides for a shared and distributed use of the game. The core objective is to create a situation that brings the students together in a way that encourages them to experiment with different designs by making compromises, overcoming conflicts, and working within the constraints of the game. The underlying theory of this model is that by encouraging collaboration among each other when addressing the different obstacles and variables encountered, the students will have a better understanding of their own behaviour and the behaviour of other members. Thus, the students will intuitively contemplate the diverse and beneficial methods of collaboration required for practices between trades.

Keywords. Pedagogic game, Lego bricks, collaborative design work.

1 Introduction

Throughout the competitive character of the market, product design is affected and driven by the constitution of multidisciplinary teams capable of efficient collaboration. The collaboration practices between trades become an essential catalyst for creative sharing of skills. By its socio-technical characteristic, the collaboration is a relatively complex phenomenon to study and to formalize in the organization [1]. The interaction between the individuals themselves, as well as the interaction with the surrounding systems (objects, context, etc.), creates major concern in the academic and industrial world. We must keep in mind that collaborative work starts at the moment the actors exchange opinions on the existing information, share their experiences, define common targets, and compile

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data and capabilities. All of these activities are carried out together with a common objective. However, this description hides both the difficulties and the obstacles. We share Reynaud's perspective on this affaire. He notes, "the individual competencies are as fought as they are added" [2]. In regards to the social aspect of the project, the multi-disciplines usually involves actors of various departments, possessing complementary skills and of different cultures (reference frame, vocabulary, formation, history, experience, etc.), yet with each participant envisioning the creation of a different end product. As a result, the participants independently develop their own strategies when forming personal objectives and criteria of evaluation. The study of collaboration is relatively complex in the industrial context. Likewise, the education of individuals is also a major concern for most academic institutions and particularly among engineering institutes. In the end, preparing future engineers with real technical knowledge while allowing them to acquire collaborative competencies remains a challenge for these institutions. The actors' technical and economical knowledge is constantly growing. Due to this issue, engineering institutes must teach an ever greater number of disciplines to their students. Therefore, this situation leads to difficulties in comprehending other areas of expertise and generates significant problems when exchanging and sharing among trade interfaces [3]. Nowadays, the training of individuals focussed on the development of know-how and aptitudes of collaboration remains a major problem. In fact, it is necessary to recognize the strong contextual character of the collaboration from its numerous "parameters" (personal development, individual and group psychology, enterprise culture, power game, general working habits, etc.). For this reason, the aptitude to collaborate is often perceived as a competence that is essentially learned by experiences and real situations. It is accordingly very difficult to reproduce such a training environment when striving for a pedagogical goal. However, the internships and student projects are the first answers delivered by the academic institutions to encourage their future engineers to act as actors of collaboration in real situations. In this paper we propose a design game with the intention that engineering institutes use it as a pedagogical tool for the teaching of collaboration. This game, essentially based on LEGO blocks, was developed to simulate the multi-disciplined design of a technical object. Also, the game aims to lead a group of students to experience a constrained situation where everybody's participation is needed. Even though the students attend the same class (or course), they all have different backgrounds (normal or technical high school, etc.) and engineering options (General Product design, industrial organization or Process Automation Master). These differences enable the groups to be heterogeneous, although not entirely representative of the diversity to be found in the industry and enterprise world.

More particularly, we adapted several concepts of the game "Delta Design" (which was developed at M.I.T by Bucciarelli) and these will be presented in part 2 of this article. Part 3 of this article will be comprised of our presentation of the game. In the final part, we will conclude by distinguishing the limits and perspectives of our work.

2 The Delta Design game

In the Delta Design Game [4] game, each of the four players receives two documents. The first part presents the team composition and target. This directive also specifies the global task to be undertaken by detailing the design requirements of the house. This first part is the same for all participants. The second part of the document, different for each trade, outlines the essential requirements for the correct execution of the role assigned to the player.

2.1 The design objectives of Delta Design

In the Delta Design context, life on DeltaP is presented as being far from what we actually have on earth. First of all, DeltaP is not a planet, but in a planned flat world. Next, the teams design in a 2-dimensional space; thus, not in 3-dimensional as most are accustomed to. In order to ensure that the designed product respects specifications (requirement sheet) and that it pleases the client in terms of aesthetics and function, a representation on a simple piece of paper is sufficient. The team must design the residence by assembling these equilateral triangles in either red (heating triangle) or blue (cooling triangle) formations. Due to the use of triangles as a residential building component, their aesthetic and thermal functions are much more complex than their form and dimension. Therefore, each team's task is to design a house that takes into account and integrates all of the constraints and tastes of the customer, as well as the characteristics and components of the triangles.

2.2 Delta Design Collaboration

The design team is composed of a project manager, a structural analysis specialist, a heat engineer, and an architect. One of the directives is to hide the specification document between the members of a same and opposing team. After this common game, each player receives a document that includes the objectives and constraints of its trade, but this is something we will not explain here.

It is important to note that these rules are sometimes vague and subjective and can be precise and formal. By analysing the various trade rules given to the players, we realise that they were defined in order to create alliances and oppositions between the players. Afterwards, this equation allows us to observe opportunities for collaboration and negotiation between players who address their respective constraints while building the house. The foremost interest of Delta Design game remains the analysis of the collaboration "highlights." An external viewer or a set of viewer-player can do this analysis by trade. While each Delta Design experience produces new results, we may still take notice of the numerous "highlights" that frequently punctuate the development of the experience. Frequently the conversations between the players are interesting: a balance of power is settled between the players, and sometimes, a social hierarchy appears. During the short presentation of each trade the final subject (i.e. designing a new house) is temporarily left aside to profit from another matter: the structure and the hierarchy of the group. At this moment, the personalities of the group appear: the stronger players try to impose and lobby or their preferences in a dominating way over the other trades. Subsequently, there is a variation to interpret the instruction of non presentation of the specification document. Indeed, because the specification document is not shown and thus the players cannot talk or exchange about it, some people see it as a form of concurrence within the same group. On the other hand, some people reinterpret their assigned constraints by organising them hierarchically in an opportunist way.

2.4 Delta Design : results and limits

Analysing the corpus, the pictures and videos of a session with Delta Design allow us several opportunities for insight and observation of individuals in a collaborative situation. In this paper, we will not develop the pedagogical interest of this approach as the reader may consult the paper [5]. Thereby, through reflective analysis [6], he can better understand and analyse his own behaviour during a collective action. However, we have identified some limits of the Delta Design game.

First of all, the future design product engineers occasionally have a lack of enthusiasm or concern for the experiment. This is related to the fact that the final objective of the experiment is the design of a house assimilated to the formation of architecture and with characteristics not focused on the mechanical product technology.

The representation of the object to be designed (under the triangle assembly) seems to be too abstract to solicit more interaction between the players. Moreover, the 2-D format differs from the 3-D formats (CAO) traditionally used in product design.

The game format imposes its utilization at the present moment and does not allow for a test in a distributed environment

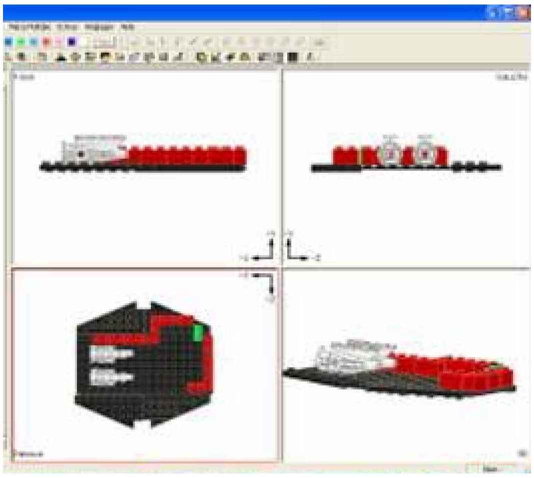
Taking these limits into consideration, we designed a different game focused more upon mechanical product design. This aforementioned game is presented below.

3 The new design game based on Lego blocks

3.1 The design game's objectives

The objective of the proposed game is to design a space shuttle (cf. example figure 1) by assembling Lego® blocks while respecting various constraints. The choice of block is essentially based on upon its ease of use, its allowance for building, its resemblance with mechanical products (an airplane, a car), and its functional free software used (ex: MLCad) to remotely build and share virtual assembling models. It is important to note that numerous pedagogical games (engineering specific, marketing formation, and enterprise coaching) have been designed using these types of blocks (http://www.seriousplay.com/).

Figure 1. Examples of space shuttle built with the software MLCad



3.2 The multi-trades team's mission

This is an extract of the introduction that each player will receive once the team is composed.

Our galaxy is not only composed of these atoms, but also of a magnitude called the "slowness" that impregnates the matter and modifies its characteristics. You have to design the slowness as a homogenous field of anti-energy of variable potential. The slowness is included in a standard scale of +15 L° and -15 L°. However, this scale is not always adapted. The average slowness of a living organism is 0 L° and is endurable without corporal damages at around 5 L°. It is important to realise that it is impossible to partition slowness and use its potential and effects. The properties of certain blocks exist for that purpose.

In order to achieve the global objectives, we have created a random draft principle to draw the targeted values. We aim to use this to define the different targets for the different teams, for example: a team will be in charge of designing a space shuttle to transport x number of individuals to a speed y, for a given autonomy of t. Each different type of transport has different characteristics and obligations. All of the variables are taken into consideration in the common specification sheet. The elementary blocks to construct the final product are used by means of a reduced and specific database, obtained from the set of Lego® type blocks. This database can be used virtually with the free software MLCad (http://www.lm-software.com/mlcad/) or in a tangible way in the event in which the Lego® blocks have been actually purchased. The blocks are differentiated by their attributes (form, type, and color). These attributes also give the blocks special characteristics in terms of weight, cost, mechanics, or heat resistance.

There are 5 types of blocks: red represents heat resistance, pink represents energy reserves, blue represents mechanical resistance, yellow represents aerodynamics, and green represents ergonomics and aesthetics. Weight, heat, mechanical resistance, and cost characterize each block. There are three types of assemblies that can be made to fix the blocks: the high heat resistant assemblies, the structural assemblies, and the standard assemblies. Two motor families (big and small) with non-proportional power, weight, and heat diffusion parameters are proposed. Each model within each family has similarities (the "sport" model which is powerful, but not economic; the "big carrier" model which is cheaper; etc.). Different examples of forms are available as well: rectangular wings with yield a high carrying capacity, but are not well adapted to speed and offer high air resistance; "delta" wings which yield high performance, but need more power, and thus more fuel; etc. The dimensions solely characterize the frame plate (the number of "wedges"). They can be fixed amongst each other by means of mechanical resistance type blocks.

In this manner we restrain the students and force them to enter into an unknown world within which their calculations will be reassuring and manageable.

3.3 The rules from each discipline in the design game context

Within the game, we have a series of rules that belong to each of the implicated disciplines and assigned to each of the design game players. These different disciplines are: the assembly manager, the motor engineer, the ergonomist, the wings' responsible and the "slowness-man". We have expressed the rules in both a quantitative and subjective manner. This enables us to condition our work habits necessary for the project and avoid our tendency to only cooperate when required to satisfy the constraints. The rules are designed to encourage the actors to cooperate, negotiate, and to converge on an acceptable compromise for everyone.

The Assembly Manager must guarantee the budget is followed. He is also responsible for the surveillance of the project's energy consumption. "It is imperative that your point of view is taken in account in every design choice made by your team, all along the game. Only you are to keep the budget and the energy usage to an acceptable level ". He must calculate the material costs and the salaries given to the team members. The motor engineer has the following mission: to choose the dimension for the motor(s) to be used for the shuttle, to place it (them), and guarantee their proper operation under any and every circumstance. He is also responsible for the motor power supply. The "slowness-man" requirements begin as follows: "You must choose the shuttle internal slowness from the beginning, as it influences the shuttle speed. Once it has been chosen, you must disperse the slowness and keep it contained to the best of your ability". The ergonomist must define the internal organization of the space shuttle. "the distribution of rooms will have an impact on the design choices for which the rest of the team is responsible. Think about the consequences of your own choices. You are responsible for the comfort and practicality within the shuttle. It is your duty to make everybody follow the slowness imposed for the each room by the specification sheet."

Lastly, the wing's responsible must choose "the size of the wings, which responds approximately to the following law: Sails = 30 % number of frame wedges* Km*Number of motors. It is also necessary for the wings to be three times bigger than the frame length.

Some disciplines have calculation rules that must be applied in order to calculate various parameters (speed, power, consumption, slowness) and also to calculate the dimension of various shuttle components (motors, batteries, wings, compartments).

4 New Lego® game tests: very encouraging results

We are implementing different tests with engineering and Ph.D. students. To this day, two groups have enabled us to experiment with new rules and a new functioning mode. Within its imaginary world, the game that has been proposed permits the users to be placed in an ambiguous environment: pleasant and unnerving at the same time. The appeal of the "CAD utility" of the Lego® game is undeniable compared to the triangle papers of the Delta Design Game. We assist to a true passion on the screens that present the CAO model of the space shuttle (see figure 2). However, we observed that the computer strongly restricts the number of manipulations and limits the sharing of the intermediate design object. Moreover, a future improvement could consist in adding physical Lego® blocks in order to construct the first physical prototype of the space shuttle before producing it using MLCad.

Figure 2. Photo taken during the first Lego® game tests

5 Conclusion and perspectives

After the tests and the finalization of our rules, we would like to propose an experience between several institutions (engineering schools, universities) in order to test this game in a distributed way (between several teams) and at distance (at different locations). The goal of our game is to approach socio-technical practices [7] of the engineers that use at the same time i) CAD models (in our case, the MLCad model), ii) proprietary utilities (in our game, the team could prototype the first versions of the space shuttle with real physical Lego® blocks). We place ourselves in the current movement that aims at the mobilisation and mutualisation of academic means, in particular in the case of the training of complex capacities such as the job collaboration. When fulfilling this condition, the young modern engineers [8] could be integrated more easily in the socio-professional networks. The game will be presented in the form of free tests to the participants of the CE 2007 conference.

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