Supporting Design Learning with Design Puzzles

Some Observations of On-line Learning with Design Puzzles

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Keywords: Design Puzzles, Design Collage, Puzzle-Making, Andragogy, Game Play

Abstract: The design process is a puzzle-solving process. Two groups of researches that share many similarities with Puzzle-solving design process are the process of game-playing and playful learning. The main argument is using the “playing” characteristics to amplify and explore the learning process, furthermore the design process. In addition, puzzles imply playful exploration that utilizes the characteristics of “playing a game” as “solving a puzzle”. Puzzle making and puzzle solving provides an incremental exploration mechanism that is more intuitive for design learning. For understanding and realizing puzzles in design learning, this research is divided into two stages of researches—manual design puzzles and interactive design puzzles. By analysing the outcome from manual design puzzles, this research proposes a framework called (interactive) “design puzzles”. The conceptual and implementation framework of this view of design is elaborated in this paper as well as a particular design puzzle called puzzle collage is described as the realization of design puzzles.

1. INTRODUCTION

The design process is a complex human behaviour. One common practice is to apply a metaphor to explain such a complex behaviour. It is called a model of design. Two well-known models of design are design-as-search (Woodbury, 1991) and puzzle-making (Archea, 1987). By decomposing design problems into a set of hierarchical sub-problems, design as search models design process as an iterative process of searching for design solutions in related to the design problems. While design-as-search shows an effective mechanism, puzzle-making argues that designers cannot solve a design problem unless they can define the design problems within the
solving process—design process is about making the puzzles rather than solving the puzzles. Design as puzzle-making depicts different aspects of design (as puzzles). These two models of design are compliment to each other in a way to frame a design process (puzzle solving and puzzle-making). Instead of emphasizing on either puzzle making or puzzle solving, this research intends to develop a design supporting system that integrates both concepts as a model of design.

Two groups of researches that share many similarities with Puzzle-solving design process are the process of game-playing and playful learning. The main argument for the process of playful learning is by using the playing characteristics to amplify and explore the learning process, furthermore the design process. In addition, puzzles imply playful exploration that utilizes the characteristics of “playing a game” as “solving a puzzle”. Therefore, within the scope of the game-playing researches, people tend to create a learning platform entirely within game environment such as video games or networked 3D virtual game environment.

Briefly speaking, solving puzzles requires a clear and deterministic goal, and also permits the possibility for creative and alternative searches (Akin and Akin, 1998). This allows users to explore the alternative solutions and be motivated in their learning process. Therefore, another group of researches is online design learning. A model of learning is called andragogy that provides a conceptual model for describing how to motivate the learners in various self-constructive situations. Three groups of relevant researches show different concepts of playing puzzles in the interest of this paper. The relations are shown in Figure 1.

Figure 1. The relation between design as game play, playful design, and self-motivation

Insights of each group of researches in relation to this research will be described more in details in the following sections.
1.1 Design as a playful learning process

Through playing, one of metaphors for design learning, this specific group of researches implies technical and methodological refinement over a standard design exploration process. Such as (Radford, 1997) provides a simple mechanism for exploring the form-making process. Further developed by (Woodbury, Shannon, et al., 2001; Woodbury, Wyeld, et al., 2001), while using the name of “game”, these researches tend to focus on the conceptual level of play (Klugman and Smilansky, 1990). Every game specified in these papers is using the concept of playing games at its conceptual model level by applying the metaphor of “playing games” on either teaching design or modelling design learning. The exploration of design-as-search is transmitted into a playful experience. While restricting the transmission between different games, the characteristics of playful experience is unleashed that paves the route towards a puzzle-making and puzzle-solving experience.

What we learn from this group of research is its capability for exploring the design concepts following the characteristics of playful learning. Such will allow designer to think more freely and creatively, meanwhile, the puzzle-exploration process might invoke.

1.2 Using games as a design supporting tools

Design games are realized in several instances such as (Chien, 2002; Woodbury, Wyeld, et al., 2001). The results are promising and effective. To their extent, this research group goes even further into analogising the real design experiences of game playing. Such as (Lee and Wai, 2003) using game engine as a development environment for cooperative design; and (Lehtinen, 2002) using 3D video game environment for teaching and learning design. Another effective approach is to use gaming environment for design presentation as well as interaction (Sallkachat and Choutgrajank, 2003). Among those, one thing in common is that “game” is taken not just conceptually but also literally. By putting design into a well-defined game environment, the limitation as well as its significances of games can apply onto design problems in our interests.

As for the purpose of puzzles, this group of researches provides an important insight that games all have their own strength and features that can be mapped into our puzzle systems. In this case, studying the characteristics of puzzles will give us the benefits to stress the concept of puzzles back into design. Further, our system might provide the features of puzzles that all people can be familiar without re-inventing the wheel.
However, the most important issues for design learning—self-motivation and exploration strategy are hard to achieve within game-only context. We need to gain more insights from learning theory in the next group of research.

1.3 Learning design with self-motivation

From Design learning to a model of learning, we look at a group of theory that can provide significant insights for realizing our puzzle-exploration system. There are many learning theories, especially online learning, that will provide both cognitive level and computational mechanism of design learning. However, for the nature of puzzle exploration process, we tend to search for a learning theory that will provide self-conscious or motivation for interactive guidance of exploration process.

In stead of the learning theory that is based on observation of children learning, an adult learning theory called andragogy (Knowles, 1990) focuses on motivating adult learning. Motivation ends up is an essential device for guiding the interactive behaviours needed for puzzle exploration process.

While adjusting andragogy into design learning, (Chang, 2002) outlines the conceptual learning framework for our learning model. Andragogy enforces the adult learning process with six characteristics—(1) The need to know, (2) Learner self-concept, (3) Role of learners’ experience, (4) Readiness to learn, (5) Orientation to learning and (6) Motivation. Each characteristic represents certain aspect of learning with specific design constraints, thus, the puzzle-solving and puzzle-making processes in this paper.

Main strength of andragogy is to enforce the concept of self-directed learning. To say it explicitly, andragogy provides a puzzle-exploration mechanism that presents an environment for motivating designers to learn and design from their peers as well as themselves.

1.4 Towards a puzzle-base learning environment

By looking at playing games at metaphorical or system levels, playful learning environment shows some important insights for the development of our design supporting system. Therefore, we will provide conceptual structures of puzzle-as-metaphor as well as the analysis of puzzle games as our methodology towards the implementation. By integrating the concepts of andragogy into puzzle-based design learning system, the self-constructive process is then mapped as a puzzle-making process. Each individual interaction provides enough information for guiding the exploration as well as creating new puzzles. Furthermore, the motivation for solving a puzzle should provide the mechanism for the components of puzzles.
The development of design puzzles is divided into two stages and described in the following sections. First stage: manual design puzzles is to describe the accomplishment of development in WALE and its experimental outcomes for manual design puzzles. Stage two: interactive design puzzles is the further development built on the top of stage one. A workable and interactive design puzzles system is then specified and implemented based on these two stages.

2. STAGE 1: MANUAL DESIGN PUZZLES

Further understanding on the behaviours of design puzzles and learning behaviours, we conduct a preliminary experiment: manual design puzzles, using an acting role-interplayed system (WALE) (Chang and Huang, 2001; Chang and Huang, 2002). WALE (Web-based Architectural Learning Environment), is generated through a CAD subject in a positive virtual learning space. WALE is based on a game-playing learning environment for students to interact motivated and to evolve the design potential of individual (seen Figure 2). The study of WALE is facilitated with CAD tools and developed to help participants to explore possible design alternatives by acting multi-roles in the process of learning design. Several useful characteristics of digital architectural subjects on web are learned from various experiences (Radford, 1997; Woodbury and Chang, 1997). There are five primary characteristics of the web-based learning aspects are concluded that proposed acting role model of WALE are built on top of. They are 1) Asynchrony; 2) Dynamic Interaction/immediate feedback; 3) Multi-role interplay, including One-one, one-many, many-one and many-many relationships; 4) Recording/ history; 5) Game playing.

Despite that synchrony is a useful feature of web; asynchrony characteristic of design behaviour provides a more flexible design outcomes by shifting the design ideas input on web. Web offers an enormous virtual space where information is accessed and exchanged freely and fast. Thus, the features of dynamic interaction/immediate feedback are derived. The concept of multi-role proposed for students is to offer an opportunity of acting different proposition to extend their perspective views of design on web where anything is possible. The features of recording the design process (Huang, Chang, et al., 2000) and playing as a reflective action are two crucial aspects toward web-based learning.
2.1 The experiment

On the top of WALE, we have developed the first prototype of design puzzles manually as a pilot study for understanding the behaviours of puzzle making and puzzle solving on the behalf of digital media learning. The duration of the experiment is three semesters and with a group of 40-50 participants. The backgrounds of participants are mostly artists with design training. Only few have computer experiences before participating this experiment. Therefore, the objective of design puzzles at this stage is to guide and motivate participants with the digital media. In addition, each puzzle is divided into two parts: a puzzle with design media concept and a puzzle-solution evaluation. As the nature of design, the evaluation of puzzle solution has to somehow depend on the critic (the human) involvement. Three evaluation criteria applied to the puzzle are: design, technology and skill. Different criterion represents different aspects of puzzles in a particular design goal related to the learning motivation. Several online techniques such as page-hits, preferences and grading are used for quantifying the evaluation outcome.
The experimental steps are 1) using a more conventional method of curriculum at the first semester as an introduction to digital technology. 2) For second semester, WALE is used and applying with our design puzzles for a set of predefined goals within the acting role framework. 3) For third semester, the curriculum is changed to be professional skill oriented. Consequently, design puzzles developed for the third semester will require a more pedagogical approach along with andragogical methodology proposed in this research.

2.2 Some observations and limitations

As a teaching outcome, some design puzzles are successful for some participants but fail in others. With comparison of the puzzle-solution proposed by participants, we gain some observations and drawbacks of this experiment. There are five main limitations of this version of design puzzles such as the implementation platform, the domain knowledge of puzzle, the duration of experiment time, the number of participants and the will of participants.

As WALE is developed as a general Web-based learning environment, the puzzle-making and puzzle-solving facilities have to move around by using other mechanism such as digital media exploration. This is to say that puzzle in this stage is represented as a metaphorical experience rather than implementing the mechanism of design puzzles. Furthermore, solving a puzzle requires some knowledge of that particular puzzle itself. Thus a general mechanism for designing puzzles might not be feasible and useful. Also, as such experiment needs a long time to expose these puzzles for participants and allow participants to refine them. The duration time of puzzle exploration becomes more critical and inefficient in some cases. In addition, while solving puzzle participants need to either know the context or to understand the puzzle goal with instincts with time limitation. Consequently, a large number of participants decrease the communication time among participants as well as their will in solving the puzzles. As well, in our experiment, the process of puzzle solving and making is only invoked by the personal communication among participants that cannot be shared with others.

As the first pilot study, the puzzles are intended to be simpler and the hints for solving the puzzles have to be constructive and effective (Figure 4). This ends up to be an important factor for a successful puzzle. Another observation is the media. While using media as a representation, each successful puzzle should represent certain view of digital media. Several instances show that an interesting or inspiring view of digital media will motivate the participants to explore further on their own learning. The
duration time of each puzzle solving process is set for about 10 hours. The minimum is 3 hour when average time is about 8-9 hours. When an interesting and challenging puzzle has been explained, participants are more willing to spend time to explore the possibility to solve the problem than an obvious solution.

Figure 4. Relation between hints and rules

Another insight is that more successful puzzles have more inefficient or “fun” rules that will allow many alternatives or exploration to be made. For example, a design puzzle is about topological relations among geometry. The hint is push/pull. The goal is a space without space. Participants are getting into it right after using a few steps of commands instruction. Another important observation is that puzzle making provides an incremental exploration mechanism that is more intuitive for designers during the learning process. While learning affects are varied, the outcome of applying puzzle as a metaphor shows its strength in exploring and refining possibilities. The process of doing such exploration is showing promising results that motivate a further development of design puzzles in this research.

3. STAGE TWO: INTERACTIVE DESIGN PUZZLES

With the observations gained from stage one, manual design puzzle experiment, we then further specify a design supporting system by using puzzle-exploration metaphors. We called it (interactive) “design puzzles”. According to the nature of learning behaviour and rules of puzzles, the design stage in this research is taken place in an early phrase of design. With design puzzles, learning design and making design can be modelled and studied with a specific view of design. Consequently, by learning from puzzle-games, several components and their mechanism are described in the following sections as well as the characteristics of design puzzles.
3.1 Puzzle Games

Puzzle-games (Bates, 2002) are a special class of games that will require player’s logical reasoning capability to overcome the obstacle (the puzzle) in order to complete the game. Such as “finding a missing information piece” will require players to know the background of situation and reasoning it with the hints in order to solve the puzzle. According to (Bates, 2002), there are 19 types of puzzles such as mazes, criddles and cryptogram/word puzzles. In addition, such as “building puzzles” that players need to build the “missing pieces” in order to solve the puzzles can be applied on design domain. Each individual puzzle has its strength and twists that will provide some informative hints for players as well as traps. Players need to use the given hints with a set of rules in order to solve the puzzles within some particular situation or environment.

In mapping to design problems, especially puzzle-exploration, we identified six types of design puzzles according to the 19 types of puzzle games. There are 1) the geometric composition puzzles that compose 2D or 3D geometric components under the interaction with environment such as 3D puzzles; 2) design collage that using images as a symbolical meaning of design and the collage represents the outcome of design process; 3) information puzzles such as fractals or design space navigation; 4) role-play simulation with users playing different roles within different timeframe to simulate the puzzle-exploration process; 5) pattern recognition (jigsaw puzzle) using visual similarity and pattern recognition represents a simple but power design puzzles; 6) maze that can be viewed as a design space navigation process.

Each puzzle represents different design representation and aspect of puzzle exploration—puzzle-solving and puzzle-making process. To certain extend, several characteristics among those puzzle games are unleashed that will be described in the next section.

3.2 Characteristics of Design Puzzles

While studying online learning in design process, this research is applying the metaphor of “puzzle” from games and other resources onto developing an ongoing design supporting system called the “Design Puzzles’. Design puzzles while supporting the self-constructive learning pattern of design is an essential device for design by exploring the possibility of design rules. By exploring design with modifying the goals as well as generating new design with generative rules, a puzzle exploration process can then be supported by the machinery we have developed. This goes to keywords exploration or re-definition as image collage (shown in the
example). One common characteristic of above is to keep player motivated and focus with intuitive components. With the observation of puzzle game as well as preliminary experiment at WALE, the characteristics shared among them are elaborated further as followed:

1. A goal has to be clear but indirect. The goal of a good puzzle cannot be a binary choice and requires a bit of mind-twist. However, puzzle goals have to be clearly addressed and relevant to the given hints.

2. Puzzle exploration has to be self-constructive but with the potential to be shared by others online. Even puzzles are possible to be explored or solved by the cooperative work of multiple users; the self-constructive puzzle exploration is the key for learning design.

3. Hints can only provide partial information for the environment of puzzles but is enough for further exploration. Hints are the triggers for creating alternatives and decision strategic control.

4. Hints have to be intuitive and direct for shorten the duration time of puzzle solving process.

5. Rules have to be simple and manipulated directly with several entities described in hints. Rules are needed to be simple to avoid complicate firing sequence that will make the puzzle uncontrollable. In addition, rules are based on the representation of puzzles that will indeed be a set of components provided by the hints.

6. Puzzle making process is an interactive process with both rules and puzzles data. This is to say that a puzzle will not be completed unless the interacting with the users. In this case, an automatic process is rather not desired since the outcome of puzzle is dynamically made when users encounter the puzzle hints.

As seen from the characteristics described above, three key issues for an effective puzzle are the need to have a clear defined goal, some components and a mechanism to manipulate them in solving the puzzles. The clear defined goal is the design issue that will be elaborated here. The components and the mechanism are the issues we will address in the following sections.

### 3.3 Components of Design Puzzles

A design puzzle in our representation is comprised of hints, puzzle goals and puzzle rules. Each represents partial information that will direct the understanding how a puzzle can be built. Hints provide a description of situation that a puzzle is located in addition to the information players need to solve the puzzles. Puzzle goals determine how the puzzle can be satisfied or evaluated. Puzzle rules then describe how the piece of information provided by hints can be manipulated in order to satisfy the goals. In addition, with informational point of view, the outcome (the solution to the
puzzles) as well as the exploration process of any participated players should be recorded for a further examination or exploration.

We have developed a system called design puzzle that utilizes the functionality of puzzles on the behalf of design, for this view of design described above. Design puzzles while comprised of “hint”, “puzzle rules” and “puzzle goal”, provides a way to describe our teaching capability. Consequently, an experimental system is conducted according the theory of design puzzles described here.

4. IMPLEMENTATION AND AN EXAMPLE

With the conceptual level of design puzzles, we then describe our implementation—design collage as an experimental system for computerizing the puzzle exploration behaviours described above. The reasons for choosing collage as our first implementation of design puzzle is its simplicity in both metaphorical and implementation levels. With such simplicity, we can then focus and further develop the systematic issues and the interactive mechanism of design puzzles.

4.1 Implementing a puzzle-making environment

For realizing the design puzzles, a system called “design puzzle zone” has developed in this research. The system is comprised of three system blocks—puzzle-making facilities, puzzle rules and puzzle server. The relations among these system blocks are shown in Figure 5.
Briefly, the puzzle server is developed using LAMP (Linux, Apache, MySQL and PHP) approach with communication with a rule-based inference engine for resolving and editing the puzzle-rules created by the users at the client side. The interface of puzzle-exploration is built on top of Flash/ActionScript with a Web-based interface for its rich text capability and integration with a server. Figure 5 has clearly demonstrated this system concept. The details of each system block are described as followed.

Puzzle-making facilities comprise several tool-smiths allowing designers interactively create their own puzzles, control the exploration strategy and display the content of design puzzles. This facility will allow an extensible design puzzles to be made in respect to designers expectation and design needs. Puzzle rules and a puzzle server are another two main components of design puzzle zone. Puzzle rules provide the mechanism for simple and intrinsic rule behaviours to be made into puzzles. A puzzle server then records all the transaction between different puzzles and their exploration process according to users, process and puzzles database. Furthermore, a puzzle server will provide an access to share the learning experiences—puzzle-exploration process with others within the server domain. Or, server implementation allows the puzzles done within one server can be further searchable on the net.

For the experimental purpose, we choose representation of design collage as our design puzzle in this paper for its simplicity and design-oriented concept. While the representation and transaction between different puzzle solving stages might be different, the mechanism for rules, server and puzzle-making facilities can remain the same.

4.2 A prototype—design collage

For realizing a design puzzles system, we develop a prototype called “design collage” (an example output is shown in Figure 6) that is an implementation derived from our stage two. With designed for invoking design concepts, design collages analyse the conceptual development stages with a group of design students using puzzle-exploration metaphor. Design collage while utilizes a special view of design—image-based collage, presents a view to retrieve and incorporate the puzzle making and puzzle solving functionality.

The learning process of design collage is through converting the intention of a design sketch provided by users to generate an image collage over that intention. In Figure 6, the left side is a sketch provided by users with symbol-network attached to it, the system then generates an initial puzzle collage according to the symbolic network and keywords on the left side.
These two pair presents the puzzle-hint in our design puzzle system. Similar to jigsaw or maze puzzles, design collage as well as its concept intention—sketches and their symbolic meanings are all parts of design puzzles that users have made. By interactive defining the symbolic means as the hints for solving the puzzles, several production rules and algorithms are applied for the generative process. Further, several production rules of design collage are applied and controlled by the users for exploring the puzzle alternatives. The outcome of design puzzles is shown in the right side as the outcome of puzzle-solving/making process. Every strategic moves as well as outcome are recorded in the server with a version tag for further exploration later.

![Figure 6. An example outcome from design collage](image)

While refining the design puzzles as well as the puzzle rules users made, they would be able to redefine and further explore the puzzle-goal and its potentials. This shows the usages of design puzzles in another learning aspect. In addition, the server will be recording the puzzle exploration behaviours that can be shared among different users on that server. The puzzle rules are implemented as a set of rules that will incorporate with users in terms of generating alternatives. By using web-based search engine, puzzle collages will share with many users their collection of images as well as using web as a huge image database.

5. CONCLUSION

People are using puzzle solving and puzzle making for teaching design for both methodological and metaphorical levels. This idea is simple and effective shown in many researches, namely design games and playful learning environment. Within this scope, this particular research applies the
idea to an extent for developing a workable design system that helps exploring design more effective and motivated. Several observations are unleashed by building up a puzzle-solving curriculum on a Web-based environment. They are then led to the implementation of design puzzles specified in this paper.

As observing the outcome from experiment, design puzzles sure have their niches in terms of creative thinking as well as problem solving. With the key of learning is at the content not the facility. This is to say any good metaphor will not help the learning unless it is in the hold of an inspiring teacher. However, while taking the advantage of Web-based services, self-motivation and game-playing environment can then be achieved with just a bit of help. This will be done with a lot of efforts while using different media. In addition, the process of puzzle and its exploration process cannot be studied without the help of client/server model.

Furthermore, developing a puzzle-exploration system surely helps addressing the functionality and behaviours of using puzzle solving as design exploration metaphor. Hopefully, with this tool, we might be able to understand the strength and power of design puzzles. In a long-term research project, design puzzles described in this paper come with a set of requirements and limitation that will help develop a further exploration on the puzzle-solving process that (certainly) assist design and enhance the potential of design capability of individual.

REFERENCE


