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IISC DBOX: A GAME FOR CHILDREN TO LEARN DESIGN THINKING

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ABSTRACT

Design thinking (DT) can be a valuable tool for nurturing problem-solving abilities in school children. The objective of the paper is two-fold. The first is to evaluate the effectiveness of the DT process as a potential tool for open-ended problem-solving for school children; the second is to test the effectiveness of gamification of the DT process in terms of the extent of comprehension and learning of the process enabled by gamification. The paper presents a framework for IISC, a Design Thinking Process developed by the authors, and compares two gamified models of the DT process against one another using empirical studies that involved school children in the age-range of 14 to 18 (8^{th} to 12^{th} years of their twelve years of school education) playing the games. Feedback from the students and their mentors during the game was used as data for evaluation. The paper also discusses the limitations identified and suggested improvements of the two gamified models, and implications of these for designing more effective games.

Keywords: Design Thinking for Children, Design process, Training, Gamification, Design education

NOMENCLATURE

μ_0	Mean
C	Concept
DT	Design thinking
DTP	Design Thinking Process
E	Evaluation
G1	Game 1
G2	Game 2
H0	Null Hypothesis
H1	Alternate Hypothesis
I	Idea
N_1	No. students who played IISC DBox 1
N_2	No. students who played IISC DBox 2
IISC	Identify-Ideate-Consolidate-Select
P	Problem
R	Requirement
S	Solution
SD	Standard Deviation

1. INTRODUCTION

Among the educational goals, the two most important are to promote retention and to promote transfer [1]. While retention is the ability to remember or recall material at some later time, transfer is the ability to use what was learned in order to solve new problems, answer new questions, or facilitate learning of new subject matter [1]. To a certain extent, the K-12 education system in India puts a heavy emphasis on achieving retention (a lower level cognitive skill), while neglecting inculcation of capabilities for utilization and application of knowledge. According to World Economic Forum (2016), complex problem-solving, critical thinking and creativity are the three most important skills required for the future workforce [2]. These skills are some of the core goals for guiding decisions about what should be taught in schools [3]. The workforce of the future are the children of now; it is thus important that these skills are cultivated in them in their early stages of education. Mayer (1992) explains the two major components in problem solving as problem representation (building a mental representation of the problem), and problem solution (devising and carrying out a plan for solving the problem) [4]. According to Kwek (2011), "design thinking is an approach to learning that focuses on developing children's creative confidence through hands-on projects that focus on empathy, promoting a bias toward action, encouraging ideation and fostering active problem-solving – skills and competencies" [5]. Scheer et.al., (2012) noted that design thinking is effective in fostering 21st century learning through its application in complex interdisciplinary projects in a holistic, constructivist manner [6]. Design thinking (DT) complements mono-disciplinary thinking [7] and should therefore be a valuable tool for nurturing problem-finding and problem-solving abilities in children. As experts foresee, innovations that stem from creative thinking during the design process are key to economic growth [8]. In a classroom setting, creativity occurs when an individual (i.e. student) interacts with a domain (i.e. design & technology) within a socio-cultural setting, and the outcomes produced are judged by members of the field who are the gatekeepers for the domain (i.e. teachers) [9]. The creativity of individuals correlates with the creativity of their designs; "designing" therefore should be a part of the education

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curriculum, with the potential of ushering in a major revolution in education right from the primary school level. Hence, there is a need for teaching the DT process to students in the K-12 education system.

2. DESIGN THINKING AND GAMIFICATION

According to Simon (1969), "To design is to devise courses of action aimed at changing existing situations into preferred ones" [10]. Design thinking (DT) is "a creative, individual-level process influenced by social-level factors (that is, high inspiration by others, high user-centricity, high prototyping, and low criticism by other), which includes attention, memory and learning and leads to an aesthetically appealing object" [11]. Here, functionality and ergonomics are also prime considerations for the object. Application of Design Thinking Process (DTP) is not only limited to the creation of objects but also to creation or modification of systems, services, policies, etc., entailing different domains like engineering, medicine, business, IT, law, etc. DT is an iterative process that involves identifying goals (needs), generating proposals to satisfy the goals, and improving both the goals and the proposals [12].

Often student lack motivation to learn, which has been associated with boredom, poor concentration in classrooms, and most disconcertingly, with high school dropout rates. There are various ways of implementing DTP into an education system, for example, by developing a syllabus and introducing it as a new subject in the curriculum; making online courses on DTP; conducting DTP workshops; or gamification of DTP. A common aspect we see between design thinking and typical games is that both demand an interactive environment. Gamification of DTP has the potential to induce fun, excitement and motivation, which are essential for making learning more effective and efficient.

Gamification is the use of game-based mechanics, aesthetics, and game thinking to engage people, motivate action, promote learning, and solve problems [13]. Gamification of learning is a way to keep students engaged, motivated, excited, and help develop positive attitude. According to Kapp (2013), there are two types of gamification: structural and content gamification [14]. In structural gamification, the structure around the learning content is game-like, and its primary focus is to motivate learners to go through the content and engage them in the process of learning through rewards [14]. Content gamification uses game elements and game thinking to alter content to make it more 'game-like' and may involve provision of game context/activities to the content [14]. The most effective gamification efforts include more than rewards, like points and badges that contain elements of story, challenge, and continual feedback as well as a high level of interactivity [13].

We discuss here about the various existing design games (viz. "Khandu", "Design thinking board game" and "Rippplr") so as to explain their features and state their limitations.

"Khandu" is a card game created in order to foster creativity and design thinking in children of ages 6 to 12 years. The game consists of 4 decks: challenges, tools, people and action cards. Players need to start with the selection of a challenge. Thirty-five tools are used for inspiration (opening the mind, connect with the environment), generating ideas and creating prototypes [15].

The "Design thinking board game" includes three phases: Investigate, Ideate and Test. Players need to travel along a predefined path. There are three types of cards facilitated by the game: challenge card, event card and character card. Challenge cards are meant to address real-world problems [16].

"Rippplr" is a brainstorming tool. It comes into use after the research phase of the project is completed. Before playing the game, the users have to be informed about the research findings that have been done so far [17].

For Khandu and Design thinking board game, the players need to pick a random challenge card and must work as a team to tackle them. Thus, a problem is predefined for the players in these games whereas an actual design process incorporates the process of problem identification as well as the process of finding solutions. Rippplr aims to help designers during the phase of idea generation. It does not include other phases of design thinking process. All these games do not provide a framework for evaluating the design outcomes and the process itself.

In order to overcome the limitations of existing games, IISC design process was implemented by the authors by developing a gamified DT model called 'IISC-DBox' for school children [18]. In addition, a systematic pedagogical framework for gamified models of DTP has been developed. The framework includes instructions of how to play the games and follow the DTP, mentors' role in the game, and evaluation of the process and outcomes of applying DTP. Two versions of this game were developed - IISC DBox 1 and IISC DBox 2.

The objective of this paper is to check, (a) the effectiveness of DT process for children for open ended problem solving; (b) evaluating the effect of gamification for learning and comprehending design thinking.

An empirical study has been conducted where the two games have been played by 38 students, feedback and outcomes have been collected from each, and the games have been compared by analyzing the feedback received from the players and mentors, so as to address the research questions listed below.

(a) What is the effectiveness of gamification of the DTP in terms of motivation and understanding? In order to address this research question, the following sub-questions have been asked:

a. How good is the level of student's enjoyment and engagement while playing the game?
b. How comprehensible are the content and instructions?
c. How necessary is the role of mentors in the game?

(b) What is the effectiveness of applying DTP for problem-finding and problem-solving by school children?

For addressing this research question, the design outcomes have been evaluated and correlated with the feedback received.

3. IISC DESIGN THINKING PROCESS

After analyzing the various activities of existing design models, in the previous work, the authors have derived a design thinking model with four broad generic stages: Identify, Ideate, Select (abbreviated as IISC) [18]. The authors call this model as

the IISC Design Thinking Process. As this game was developed at the Indian Institute of Science, abbreviated as IISc, the authors have swapped the letter positions of C and S in the I-I-C-S design stages, for resemblance to the university name. The four stages are explained in detail below.

(1) Identify: *Identify requirements* by observing habitats, empathizing and talking to people, creating a list of demands and wishes and ordering them into requirements.

(2) Ideate: *Ideate Solutions* involves enlisting process steps and generating alternative ideas for each requirement. It also involves grouping and combining alternative ideas into alternative solutions.

(3) Consolidate: *Consolidate solutions* should turn solutions into feasible solutions; this involves modelling and inspecting these solutions against demands and wishes to further modify them.

(4) Select: *Select* the most promising solution by modifying the list of requirements, prototyping solutions, analyzing against modified requirements, combining individual evaluations, and comparing the scores to select the best solution.

The four stages in IISC DTP have linearized steps. The advantage of which is, the complexity of this model can be varied by adding or skipping steps and embedding design methods that make a sub-step explicit.

4. STRUCTURE OF IISC DBox

Two games (having different features) of the IISC DTP have been developed to inculcate DTP in children- IISC DBox (henceforth referred to as IISC DBox 1) and IISC DBox 2. IISC DBox 1, consists of the elements explained below:

1) Level board: There are four level boards in the game pertaining to the four levels of the IISC DTP. Each level board has 16 positions, through which a coin would be traversed by the player. Each of such positions on a level board, bears a certain color code and a logo. The logos are indicative of the steps of the corresponding level of DTP [18].

2) Instruction cards: The instruction cards speak elaborately about each sub step of the DTP. The description bears instructions for players, along with suitable examples or analogies, thus educating players about the design process (shown in Figure 1). The games have a total of 32 cards.

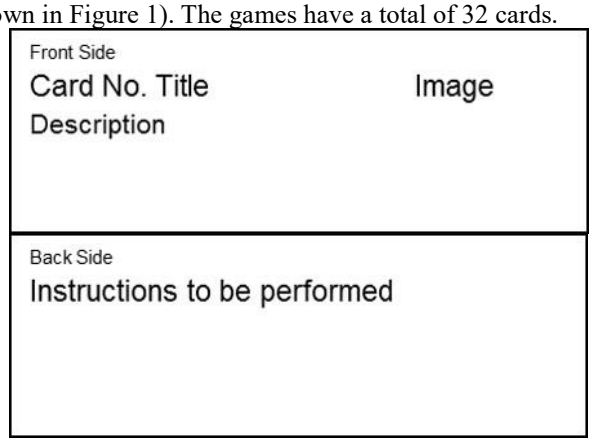

FIGURE 1. STRUCTUTE OF ACTIVITY CARDS (DESIGN STEP INSTRUCTIONS)

In addition to the level boards and instruction cards, the game contains game parts i.e. markers (avatar), customized dice, performance evaluation sheet, feedback sheet and miscellaneous items (sketchbooks, worksheets containing guidelines, on which the players would produce the task demanded of the design thinking steps).

The first game IISC-DBox 1 was tested in a school; the details of it is presented elsewhere [18]. Feedback has been collected from mentors through a semi structured interview (i.e. what did they like/ dislike about existing game/ activities, suggestions and improvements on the game). Mentors' suggestions are analyzed and grouped into shortcomings that are of similar nature. The main points from the feedback we received are the following:

a) The card contents should be more comprehensive and simplified so that students can easily understand.
b) Definitions of terms must be supported with examples where necessary.
c) Instructions given in cards and workbook should have clear goals that are distinct.
d) Need to introduce a way to keep students stay engaged, excited and motivated throughout the process.
e) At the end of each step, evaluation should be done to regulate the performance of students and keep them motivated.
f) Mentor's role is important. Need to train mentors so that they can help students to understand the content when required and can encourage students when necessary.

The second game, IISC DBox 2, was designed accommodating the feedback received from the first one. The objective of IISC DBox 2 is as follows: A team of players needs to carry out the design steps/activities of IISC design thinking by following its instruction cards. A team gets rewards; even the form of points (through coins and diamonds) by mentors and the intended end-user, after the evaluation of process followed and outcomes produced respectively. A team should have a threshold value of points in the form of coins and diamonds at the end of each design stage (i.e. Identify-ideate- consolidate- select). One DBox (the game set) will be used by one team with at least 3 players. The IISC DBox 2 has four different level-boards in the game with the visual themes: jungle, village, sea and desert corresponding to the broad 4 levels of IISC DTP. Each level-board consists of a path that needs to be traversed by the team. The path has alternate colored steps of white and brown. The white step has demarcations for the selection of the instruction cards (of design activities) and the brown steps are full of surprises. On reaching a brown step, a team needs to pick a wildcard (wildcards contain relaxation activities, aid from mentors, internet access, online help, etc.) and follow the instructions mentioned in the card. When a team reaches a step bearing a flag symbol, evaluation by an intended end-user of the design is performed. The instruction cards and rest of the game parts are the same as that of IISC-DBox 1.

4.1 Evaluation of students' performance in IISC DBox

Evaluation is the parameter that makes learning visible and quantifiable. Evaluation of the design thinking process does not

involve straight forward answers because design process does not produce any predefined outcome unlike mathematics questions do, which makes DT difficult to evaluate. As far as the evaluation of the outcomes of a design process is concerned, one must consider creativity as a major criterion of evaluation. Amabile (1996) suggested the use of experts to identify what is 'creative' [19]. For engineering design, creativity is defined as "a process by which an agent uses its ability to generate something that is novel and useful, where 'something' refers to 'problem', 'solution', 'idea', 'product' or 'evaluation'" [20]. Guilford (1986) considered creative thinking as involving divergent thinking, and proposed four measures for its assessment: fluency, flexibility, originality, and elaboration [21]. Saunders (2002) has reported that finding novelty of patterns in literature is restricted primarily to aesthetics [22]. Multiple metrics have been proposed in literature (e.g. by Shah et.al.) [23]. Most of these are not validated empirically. In addition, if a game is played in a competitive scenario, where at least two groups solve the same problem, novelty of the outcomes (ideas/ concept/ solutions) can be assessed using the method proposed by Shah. However, in the game, where different groups worked on different problems, it is difficult to implement such metrics.

For evaluation of the design outcomes in this study, we have used the empirically validated metrics from Srinivasan and Chakrabarti [24]. According to [24], the variety of a concept space depends on the number of ideas explored (quantity). In addition, an increase in the variety of ideas explored while designing should enhance the variety of concepts, leading to an increase in the novelty of the concepts produced [24]. Here, fluency relates to quantity, and flexibility to variety. We recognize that not only ideas, but also other outcomes can be evaluated using fluency and flexibility. The outcomes can be any: identified problems (P), generated requirements (R), ideas (I), concepts (C), solutions (S), evaluation (E) etc. (abbreviated as P/R/I/C/E/S). Based on this, quantity (fluency) and variety (flexibility) can be considered as parameters for evaluating the outcomes. [25] considered need satisfaction as one of the many dimensions for understanding and measuring innovation. Since the user is the ultimate evaluator of user needs, we considered the user as the final evaluator for evaluation of outcomes.

In IISC DBox, evaluation of design outcomes is carried out by mentors and end-users. The parameters used for evaluation by mentors and end-users are explained below.

a. The four performance assessment criteria to be considered by the mentors for the evaluation are: Attempted, Completed, Fluency (Total no. P/R/I/C/E/S) and Flexibility (Less similarity among P/R/I/C/E/S). The format for real time evaluation conducted by mentors is given in Table 1.

TABLE 1. FORMAT OF REAL-TIME EVALUATION CONDUCTED BY MENTORS

Attempted	1 mark
Completed	1 or 2 marks
Fluency	1 or 2 marks
Flexibility	1 or 2 or 3 marks
Total Marks	**between 4 to 8**

b. The five outcomes assessed by end-users are: enlisted requirements, ordered requirements, intermediate solutions (prototypes), resolved conflicts, and final solution in the form of a prototype.

5. COMPARISON OF TWO GAMES OF IISC DBox

As there is no other benchmark available to compare the effectiveness of the IISC DBox games, the two alternative designs are compared with each other; the two games are gamified differently as reflected in their design of level-boards and progression across levels.

Although each of the games has an evaluation process, in IISC DBox 1 no rewards are given to the players for their performance. For IISC DBox 2, rewards are given to the players based on their performance, assessed using the evaluation process explained in the last section. If a step has been evaluated as correctly performed by the mentor, the players will receive coins, whereas if the outcomes are found valuable as assessed by the end-users (based on fulfilment of needs), the players will win diamonds. For IISC DBox 2, at the end of each the level-board, players must get a threshold value of the score. Otherwise, they need to revisit the steps where the performances are not good. A flowchart explaining the evaluation steps is shown in Figure 2.

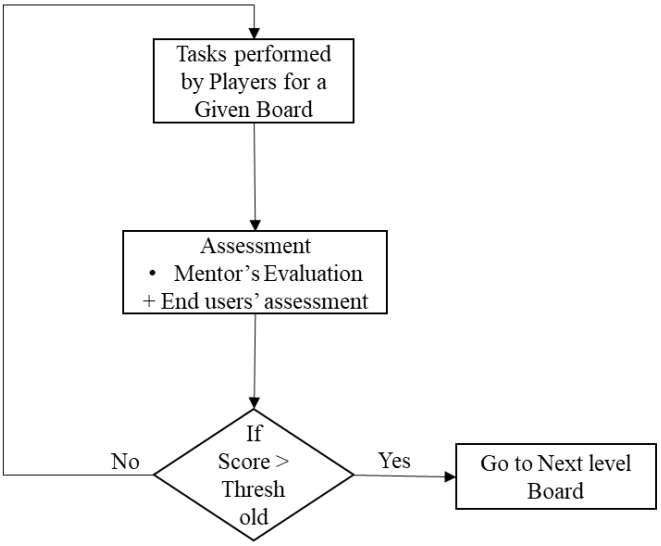

FIGURE 2. EVALUATION FLOWCHART FOR PLAYERS' PERFORMANCE

Table 2 shows the key features of both the games for comparison.

TABLE 2. COMPARISON OF FEATURES OF IISC DBox 1 AND IISC DBox 2

Features	IISC DBox 1	IISC DBox 2
IISC: Four Broad design stages	Four corresponding level-boards having logos which are mapped with the design instruction cards	Four corresponding level-boards having maps (Jungle, Village, Sea, City)
Design Instructions (total 32 steps)	In the form of normal cards (having symbol/ logo relevant to a card and mapped with the board)	In the form of clue cards (having picture/ image relevant to a card)
Evaluation	Mentor's evaluation only	Mentor's and end-user's evaluation
Corrective player action based on evaluation	NA	At the end of completing each map
Rewards	NA	Diamonds and coins based on performance at the completion of each design steps
Elements for fun and excitement	NA	Wild cards

6. RESEARCH METHODOLOGY

As explained in Section 2, the research objectives in this work are to assess the effectiveness of gamification of DT and the effectiveness of DT as a problem-solving tool. For these, the various hypotheses (H) formulated are as follows, which have been validated in Section 7. Here, questions 1.1 to 1.6 along with their hypotheses address the first research question (effectiveness of gamification of DT). The remaining questions, 2.1 and 2.2, address the second research question (effectiveness of DT as a problem-solving tool).

Q.1.1 (M) How comprehensible is the content and instructions?

H0: Students could not follow/ understand the instructions at all

H1: Students understood the instructions well

Q.1.2 How is the overall liking of the game?

H0: Players liked both the games equally

H1: Players liked one game better than the other

Q.1.3 How appealing are the visuals/ graphics of the game?

.H0: Players found the graphics in both games equally appealing

H1: Players found the graphics in one game more appealing than the graphics in the other

Q.1.4 How is the nature of the game? (in terms of monotonicity)

H0: Players found both games equally interesting

H1: Players found one game more interesting than the other

Q.1.5 How necessary is the role of mentors in the game?

H0: Players required equal mentor guidance for playing each of the games

H1: Players required more mentor guidance for playing one game compared to that for the other

Q.1.6 How much intervention of mentor is needed?

H0: Players required mentor's presence for an equal amount of time for playing each of the games

H1: Players required mentor's presence for less time for playing one game compared to that for the other

Q.2.1 (M) The mentors' opinions about the effectiveness of the game played

H0: Mentors did not find the games as effective

H1: Mentors found the games as effective

Q.2.2 The students' opinions about the effectiveness of the design thinking process

H0: Players experienced similar feeling of success after completing the tasks in both the games

H1: Players experienced a greater feeling of success after completing the tasks in one game compared to that in the other

To test the hypotheses, the authors did a questionnaire-based survey on students' and mentors' opinions at the end of game. Table 3 shows the questionnaire given to mentors. The answers of the questions are mapped to 4 labels. Answer option 1 carries a score of 1, and option 2 carries a score of 2, and option 3 and option 4 carries a score of 3 and 4 respectively. The questions given to 8 mentors are as given in Table 3.

TABLE 3. QUESTIONNAIRE GIVEN TO MENTORS

Q.	Question	Option 1	Option 2	Option 3	Option 4
1.1	**Closeness to the instructions, as followed by the students**	Did not follow instructions at all	Very different actions from instructions	Actions little different from instructions	Actions exactly same as instructions
2.1	**Overall liking of the game**	Not good at all	Good	Very good	Excellent

Table 4 shows the questionnaire given to the players. At the end of each step of IISC DBox game, the questionnaires were given, and the players' feedback were taken. An analysis was carried out on the data derived from the average values of these four levels.

TABLE 4. QUESTIONNAIRE GIVEN TO STUDENTS

Q.	Question	Option 1	Option 2	Option 3	Option 4
1.2	**Overall liking of the game**	Did not like at all	Did not like at times	Mostly liked	Liked very much, all the times
1.3	**Appeal of visuals/ pictures /logos in the game**	Not appealing at all	Okay, but not that appealing	Quite appealing	Very much appealing
1.4	**Monotonic/ boring nature of the game**	Very monotonic /boring	Boring at times	Not that much boring	Not boring at all
1.5	**Reliance on mentor for guidance/clarification while performing tasks**	Very much	Quite much	A bit	Not at all
1.6	**Do you think mentor should be there with you while doing the tasks**	Mentor required all the time	Mentor required most of the time	Mentor required a few times	Mentor not required at all
2.1	**Feeling of success after doing tasks**	Not at all successful	A bit successful maybe	Quite successful	Very much successful

6.1 The experiment

An empirical study carried out with 38 school children was to validate the above objectives and hypotheses. Children of Class 7 to Class 12 of age group of 11-17 years participated in this study; 20 of them played IISC DBox 1, while the remaining 18 played IISC DBox 2. The students were divided into two groups such that the average age of students who played using each the game matched. Both games were played in teams of four students each. A total of 10 teams were formed, 5 for IISC DBox 1 and 5 for IISC DBox 2. Team formation was done based on their age and ensuring there was a common language for communication among the team members. The teams were not allowed to communicate with other teams during and after the play. The experiment spanned for five days (16th to 20th July 2018) and had a total duration of 30 hours. The experiment was carried out at the Multi-media classroom, Centre for Product Design and Manufacturing (CPDM), Indian Institute of Science (IISc). Figure 3 shows some of the children playing IISC DBox game.

FIGURE 3. CHILDREN PLAYING IISC DBox (DESIGN THINKING GAME)

As given in the instructions, all taems followed the steps and selected different habitats for their study (i.e. canteen, constructions site, workshop, etc.). From the selected habitats, they identify and selected a problem and followed the given design process, coming up with designs and feasible solutions for solving the problem.

The mentors were from engineering and design backgrounds. The mentors were first trained on how to play the game, and the instructions were explained. Mentors' role in game were the following:

1. To ensure that players understood all the processes correctly by teaching the rules of the games, necessary skills/ methods, if required; clarifying doubts on the instructions or giving clarity on the task.

2. To ensure that players follow the process properly and evaluate their performance

3. To evoke interest: Keep students engaged and involved, by use of humor, if needed.

Apart from ensuring whether students understood the process correctly and followed the process properly, mentors' role involved observing the activities performed by the players, their engagement, motivation level, excitement level, etc. The observations were to help authors in improving the game and making the process more controlled.

Mentors were strictly advised not to help the players by proposing solutions/ hints; or criticizing hinder their ideas/ solutions. Mentors are not allowed to give a corrective response, as authors wanted to check the effectiveness of the textual instructions.

At the end of game, players generated prototypes in order to demonstrate the solutions of a selected problem. Some of those prototypes are shown in Figure 4.

FIGURE 4. SOLUTION IN THE FORM OF PROTOTYPES MADE BY PLAYERS

The design outcomes in the form of prototypes and posters were evaluated by four judges (experience with design educators of a design school) in the format shown in Table 5.

TABLE 5. EVALUATION SHEET FOR THE OUTCOME EVALUATION

Problem Identified
Significant (2 marks) / Not significant problem (1 mark)
For many (2 marks) / For few problems (1 mark)
Has no satisfactory solution (2 marks) / Has satisfactory solution (1 mark)
Solution Presented
Feasible (2 marks) / Infeasible solution (1 mark)
Novel (2 marks) / Not very novel solution (1 mark)
Likely to solve the problem (2 marks) / may not (1 mark)
Total marks (between 6 to 12 marks)

Weightages were given to the experts' and mentors' evaluation, in a ratio of 4:1. The total score was normalized into a scale of 100.

6.2 Results

- **Analysis on the feedback data collected from the mentors**

On the mentors' feedback data (both games) one sample, one tailed t-test has been used. The statistical analysis and the results are demonstrated in Table 6. According to survey options, for Q.1.1 & 2.1 (see Table 3), we have considered the value of 2.5 as an average score μ_0 (average of 1,2,3 & 4); more than 2.5 indicates students followed instructions (Q.1.1) and mentors liked their game (Q. 2.1).

TABLE 6. STASTICAL INFERENCES BASED ON THE MENTORS' FEEDBACK

Q.	No. of Mentors	Over-all Mean (μ) ($\mu_0 = 2.5$)	Standard Deviation (SD)	p- value
1.1	8	3.125	0.6	0.014
2.1	8	3.125	0.991	0.058

From the results in Table 6, we can infer the following:

Q-1.1: (Based on mentor's feedback) There is strong evidence to conclude that overall mean exceeds 2.5, i.e. students followed the instructions very closely (p=0.014).

Q-2.1: There is a mild evidence to conclude that the overall mean exceeds 2.5 and mentors' opinions about liking of the game falls between very good and excellent for both the games (p=0.058).

- **Analysis on the feedback data collected from the students**

20 students played IISC DBox 1 (N_1=20) and 18 students played IISC DBox 2 (N_2=18). On the student's feedback data, two sample, two tailed t-test has been used in order to evaluate hypothesis. The results are demonstrated in tabular form (Table 7) as well as in graphical form (Figure 5).

TABLE 7. STASTICAL INFERENCES ON THE STUDENTS' FEEDBACK

Q.	Mean		Standard Deviation		p-value
	G1 (μ1)	G2 (μ2)	G1 (SD1)	G2 (SD2)	
1.2	3.616	3.851	0.329	0.234	0.0153
1.3	3.383	3.648	0.422	0.387	0.0410
1.4	3.25	3.759	0.528	0.298	0.0008
1.5	1.78	1.77	0.623	0.471	0.9756
1.6	2.667	2.592	0.483	0.450	0.6294
2.2	3.433	3.518	0.4726	0.46	0.5779

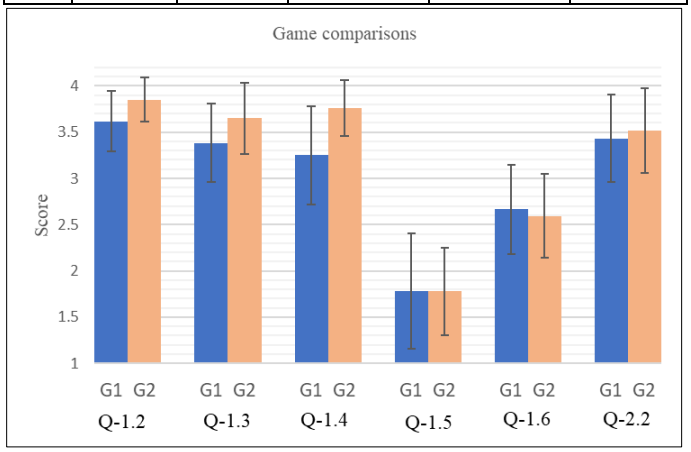

FIGURE 5. MEAN COMPARISON FOR DBox 1 AND DBox 2

From the result from Table 7, we infer the following:

Q-1.2: There is strong evidence to conclude that students liked IISC DBox 2 slightly more than IISC DBox 1 (p=0.0153).

Q-1.3: There is strong evidence to conclude that IISC DBox 2 is more appealing than IISC DBox 1. (p=0.0410)

Q-1.4: There is strong evidence to conclude that monotonicity is lower for IISC DBox 2 with respect to IISC DBox 1 (p=0.0008).

The above three inferences show that inclusion of rewards and surprise factors led to a higher engagement with the (second) gamified design thinking process.

Q-1.5: There is no strong evidence to conclude that reliance on mentors for DBox 1 differed from DBox 2. Reliance on mentor was required in both games equally while playing the games.

However, in both the games, the intervention of mentors was not always needed (**Q-1.6**). Students' opinions about the feeling of success were high in both the versions. (**Q-2.2**)

- **Analysis on the outcome evaluation**

The data collected were analyzed. Based on the calculations, the maximum and minimum scores were given to a team, which varied between 48 and 100. By combining outcome evaluation and process evaluation marks, the average score achieved by the teams stand at 78. This score is greater than the average score 74. So, we can say that the outcomes' values fit above average performance for both the games.

- **Analysis on the mentors' feedback (interview)**

At the end of the workshop, apart from using the feedback form, mentors were interviewed with whom and where questions. Keeping mentors' advice and suggestions in mind we continuously updated the content and features of the game. For example, after receiving suggestions from the mentors, we took following actions as necessary in subsequent workshop sessions.

- Simplifying instructions in the card
- Adding instructions
- Adding illustrations in the card
- Improving pictorial presentation in the card

Mentors observed that in a team the contributions of the individual players were not equal in the game. In the current game, rewards are given by only considering the performance of a team as a whole. But, according to Slavin (1990), in co-operative learning, giving rewards to a group while considering individual performance has positive effects on the performance [26]. The evaluation plan is, therefore, considered to be changed based on the above literature.

7. CONCLUSON

From the opinion of mentors on the liking of the games and the students' opinion of the success of the game, we can argue that by and large IISC design thinking has been an effective tool for problem-finding and problem-solving. The reflection of this result can be seen in the evaluation of the outcomes. In addition, gamification of the DTP is more effective (less monotonicity, more interesting) especially in the presence of rewards and fun elements. In addition, mentors play vital role in guiding students and evaluating activities through the process of design thinking.

The overall conclusions are that the results indicate the potential for both design thinking as a learning tool for open-ended problem solving, and gamification as a way of teaching design thinking.

8. SUMMARY AND FUTURE WORK

The paper presents a simplified model for teaching design thinking process (DTP), and two gamified versions of the DTP for teaching DT and learning of open-ended problem solving in school children. A framework for evaluation of the process and outcome of playing the DTP has also been proposed. The two games developed have been played by school-children and statistical analysis performed on the empirical data gathered in order to check the effectiveness of gamification of DTP, as well as the effectiveness of teaching design thinking as a potential tool for open ended problem solving.

However, the work is still preliminary in that while overall results are encouraging, there is scope for improvement in reducing dependence on mentors and improving the surprise and fun elements in the games. Testing on larger and more varied groups is also necessary. Overall limitations and associated future work delineated below:

The parameters for evaluating the design process as well as its outcomes need to be expanded for a more detailed analysis for making the gamified DT models more effective.

In the current tests, even though students came from different age groups, all were tested with the same game and same level of details of the DTP. The content of the DTP could be extended, with appropriate modifications, for these to be tunable at various levels of school education. Also, testing of the DTP needs to be calibrated to different age groups, and their effects need to be evaluated, by applying on a larger number of students with varied backgrounds and age groups. In addition, an online version of the game, as opposed to a physical version, has further potential for enhancing assessment and providing corrective feedback while making physical presence of a mentor non-essential. The online game can be monitored distantly and can be accessed from rural and remote areas through the internet.

Further, as to how well cognitive processes and reasoning abilities of school children have been influenced by their training in DTP need to be investigated.

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