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Chapter 85
A Gamified Model of Design Thinking for Fostering Learning in Children

Rahul Bhaumik, Apoorv Bhatt, M. C. Kumari, S. Raghu Menon and Amaresh Chakrabarti

Abstract Design thinking is a process that is used to systematically find goals, generate proposals to satisfy the goals, and develop these until satisfied; the areas of application are intended to be universal. This paper proposes a simplified model of design thinking called 'IISC' (Identify-Ideate-Select-Consolidate), a gamified version of the design thinking model called 'IISC DBox' for use by schoolchildren, and a generic framework for the assessment of gamified models of design thinking. The framework to assess the 'gamified' model, takes into account the nature of the constituent elements of the game, and also the outcomes and feedback of the players involved in the game. The assessment framework not only highlights the potential and effectiveness of the model but also throws light on the areas of its future improvement.

85.1 Introduction

Design thinking is the cognitive process from which design concepts emerge [1]. It is an iterative process which involves identifying goals (needs), generating proposals to satisfy the goals, and improving both the goals and proposals [2].

R. Bhaumik (✉) · A. Bhatt · A. Chakrabarti
IDeaS Lab, Centre for Product Design and Manufacturing,
Indian Institute of Science, Bengaluru 560012, India
e-mail: rahulbhaumik@iisc.ac.in

A. Bhatt
e-mail: apoorvbhatt@iisc.ac.in

A. Chakrabarti
e-mail: ac123@iisc.ac.in

M. C. Kumari · S. Raghu Menon
Design Innovation Center, IISc, Centre for Product Design
and Manufacturing, Indian Institute of Science, Bengaluru 560012, India
e-mail: kumarimc@iisc.ac.in

S. Raghu Menon
e-mail: raghumenon@iisc.ac.in

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A game is a system where players engage in an artificial conflict, defined by certain rules that result in a quantifiable outcome [3]. Gamification uses game-based mechanics, aesthetics, and thinking to engage people, motivate action, promote learning, and solve problems. Gamification considers some elements from game design and incorporates into a content that is to be learned by the player. It can be categorized into two types: structural gamification and content gamification [4]. The first type uses game elements to propel a learner through content with no alterations to the content. The second type 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.

According to a report in 2016, India has 47 million students dropping out of school by the tenth standard [5]. Data from the National Sample Survey Office (NSSO) shows that 13 out of every 100 Indians between 5 and 29 years did not attend school or dropped out because they did not consider education necessary [6, 7]. A study conducted in a high school in Canada showed that often the students lack motivation to learn any coursework or extracurricular activity, as reflected in their poor concentration in class or boredom, which in many cases also leads to high school dropout. [8]. Students are bored because the things they are given and told to do in school are perceived as trivial and dull, making limited and narrow demands on the wide spectrum of their intelligence, capabilities, and talent [9].

The objective of this study is to develop a framework for both analysis and design of a 'gamified' model to nurture design thinking in school students.

85.2 Potential of Design Thinking in Education

Implementation of design and technology in schools was initiated from 1990 in the state schools of England and Wales for children aged between 5 and 16 years [10]. Doreen Nelson, a US-based educator, pioneered design-based learning 35 years ago that has exhibited dramatic improvements in the achievements of K-12 standard students [11]. According to Dunne [12], design activities were meant to go beyond knowledge and skill and include practical wisdom. In Indian school education system, where dropout rates are very high, a productive and creative workforce is possible only by addressing the need for innovation and creativity at a young age, preferably from the primary years [13].

Tim Brown, CEO of IDEO, states that 'design thinking' widely adopted by designers, can also be used by other individuals and groups like business organizations to foster innovation [14]. Innovation happens in three phases: 'inspiration' which is the problem or opportunity that motivates the search for solutions; 'ideation' which is the process of generating, developing, and testing ideas; and 'implementation' which leads the way for the idea to reach the market [14].

Design thinking arguably can be followed by an individual to develop a solution for problems at various levels of complexity; and in the process of doing so, the person learns as to how to solve a problem that is relevant for the learner or someone else.

85.2.1 Current State of Design Thinking Education in India

Number of design programs (graduation level and onwards) in India grew from 2 in 1960 to 15 in 2006. But the lack of mass awareness about design and research into design, and the nature of formal education system, which predominantly promotes analytical thinking, are the major obstacles in promoting design education [15]. Presently design programs in India are predominantly taught at graduate and post-graduate levels in schools like National Institute of Design, Indian Institute of Science, Indian Institutes of Technology (IITs), School of Planning and Architecture (SPAs) and other privately run institutions offering courses in various design disciplines (industrial design, communication design, fashion design, etc.) [15].

It has been observed that the instruction material primarily used for teaching design thinking is in the form of handouts, printed lecture notes, online lecture notes, etc. Besides, there are several 'design method cards,' e.g., from IDEO, SUTD, Oblique, DSKD to help designers and general enthusiasts with the process of designing. However, it is not easy for designers to obtain an overview of a card system and to decide which card system is best suited for coming up with a design solution for a particular problem [16].

85.3 Gamification of Design Thinking: The Proposed Framework

The authors have developed a design thinking model by analyzing and combining the various activities from existing models (e.g., [17–19]) with four broad generic stages, that are further divided into sub-steps (Table 85.1). The four stages are: *Identify Requirements* (involves observing habitats; empathizing and talking to people; creating a list of requirements as to what is to be achieved; and ordering these into demands and wishes), *Ideate Solutions* (involves enlisting process steps for the activities in the observed habitat; generating alternative ideas for each requirement; grouping similar ideas; and combining alternative ideas into alternative solutions), *Consolidate solutions into feasible solutions* (involves modeling solutions; analyzing these against the demands to modify them; and analyzing these against the wishes to further modify them), and *Select the most promising solution* (involves revising the list of requirement; prototyping solutions; evaluating against revised requirements; combining individual evaluations; and comparing the aggregated scores to select the best solution).

Design activities typically involve a team with multiple people in a project. Playing a game can encourage cohesiveness among players and motivate them toward a common goal, reflecting on the progress. A game that elicits a play to guide and motivate players into design thinking, in contrast to monotonically responding to a set of guidelines in a printed document, can prove more beneficial

Table 85.1 Design thinking steps in our proposed framework and their potential impact on learning objectives and subsequently deriving their favorability to the learning approaches

Learning objectives		1	2	3	4	5	6	7	8	9	10	Approach			Implications	Elements for 'gamification' content
												B	Cog	Con		
Identify problems	Observe	✓	✓	✓								H	M		Instructions to look at things from a 'new' perspective	Use of examples
	Empathize & talk to people			✓									M	H	Interaction with people/storing information in mind	Examples/motivation to shed inhibitions
	Create a list of requirements			✓	✓	✓							H		Retrieval of information in mind	Use of examples/ analogies/outliners
	Order requirements				✓	✓							H		Restructuring + retrieval of information	Analogies/organizers
Ideate solutions	Imagine process steps						✓						H	M	Recalling and organizing information in mind	Use of analogies/use of examples/storyline
	Generate alternative ideas					✓	✓	✓	✓			H	M	H	For 'new' methods, the learners can learn fundamental steps before attempting complex steps	Provision for spot practicing/use of examples/storyline
	Group similar ideas						✓						M	H	Organizing information in mind/engagement in social negotiations	Instructions for peer verification
	Combine alternate ideas for alternate solutions						✓	✓				H	M		For 'new' methods, the learners can learn fundamental steps before attempting complex steps	Provision for spot practicing/informative feedback/use of examples

(continued)

Table 85.1 (continued)

Learning objectives		1	2	3	4	5	6	7	8	9	10	Approach			Implications	Elements for 'gamification' content
												B	Cog	Con		
Consolidate solution	Model/prototype each solution							✓					M	H	Information retrieval + co-learner interactions	Analogies may be presented
	Analyze each solution against demands							✓					H	M	Information organization/ retrieval + peer negotiations	Instructions for peer negotiations
	Modify solution to resolve conflicts									✓	✓		M	H	Information retrieval + peer negotiations	Examples & analogies
	Analyze each solution against the wishes and modify them									✓	✓		H	H	Information organization/ retrieval + peer negotiations	Examples & analogies/instructions for peer negotiations
Select solution	Revise the list of requirements			✓	✓						✓			H	Social interactions + peer negotiations	Motivation for social interactions
	Model/prototype each solution and evaluate against each requirement							✓	✓	✓			H	H	Information retrieval/ restructuring + peer interactions	Analogies/examples may be presented
	Combine individual evaluations, for each solution				✓			✓	✓			H	H		Introduction of new methods/ systems	Use of examples
	Compare aggregate evaluation score									✓	✓		H		Information retrieval/ organizing	Use of examples

Legend: The ✓ symbol refers that a certain step in the design process satisfies a certain learning objective. *H* stands for 'highly' favored; *M* stands for 'moderately' favored. *1* Observe one's environment or world, *2* Perceive and become aware of the processes occurring in the environment, *3* Perceive and become aware of the social (human) processes and systems, *4* Identify relevant information in memory, *5* Store relevant information in memory, *6* Utilize stored information to respond to new circumstances in environment, *7* Respond/act to circumstances, *8* Make strategies/thumb rule for Response/action, *9* Improvise strategies for better response with respect to new circumstances, *10* Gather feedback/give self-feedback for future response (contemplate) (*B* behaviorist, *Cog* cognitivist, *Con* constructivist)

for the learners. Hence, the authors thought of developing a 'gamified' version of the aforementioned design thinking model which can be played by school students.

Based on authors' analyses of the importance of incorporating design thinking in educational curriculum, using [20] as the broad basis, a set of preliminary learning objectives was formulated by the authors. Table 85.1 not only proposes the relations between design thinking steps and the proposed learning objectives, but also the importance of design thinking in enabling betterment of day-to-day living.

In order to reinforce the learning of 'learning objectives,' the designer should adopt an appropriate learning approach for a particular design thinking step and extract/ adopt suitable elements (depending upon the 'approach') to determine the structure and delivery of the instruction in a 'gamified' model (see Table 85.1). A good learning approach is one that helps communicate and transfer knowledge in the most efficient and effective manner, by combining the best of behaviorist, cognitivist, and constructivist learning approaches. This, however, depends on the content to be learned and the learner's abilities [21]. In the twentieth century, learning paradigm shifted from behaviorism through cognitivism to constructivism. Behaviorism mainly promotes learning of predefined skills; cognitivism is learning focused at learner's cognitive and mental levels; constructivism is better suited for solving ill-defined problems, by recollecting one's experiences and through social negotiations [21].

In Table 85.1, the authors have also asked a set of questions for each learning approaches against the design thinking steps to determine their favorability for adoption. To determine if the learning of a content is favored by behavioristic learning, the questions asked by the authors are [21]: *Is learning of the 'content' highly favored by conforming to predetermined standards? Is learning of the 'content' favored by repeated practice of desired responses to improve performance? Is learning favored in step-by-step process from simple to complex scenarios?* Similarly, the questions asked to determine if the learning of a content is favored by cognitivist learning are [21]: *Is learning of the content highly favored by focusing on mental associations and processes? Is learning of the content favored by mental planning, goal setting, and organizational strategies (by the learner himself) that leads to a response?* Finally, the questions to determine if the learning of a content is favored by constructivist learning [21]: *Is learning of the content highly favored by learner's activities and past experiences? Is learning favored by interacting, debating, discussing, and negotiating with other co-learners? Is learning favored by creating novel and situation specific understandings by the learner?* By asking each such question against the content to be taught (the design thinking steps in this case), the authors have decided if the teaching of the content is highly, moderately, or negligibly favored by a certain learning approach.

By combining elements from [3, 4] and also taking inputs from Table 85.1, the authors have come up with six broad parameters, which can act as a checklist to arrive at a design for a 'gamified' model for the design thinking process (as discussed in Sect. 85.3). The parameters are:

1. *Information structure and delivery*: This is the data on the content of the game (e.g., instructions, descriptions), and how it is organized, structured, and presented to the player.
2. *Response*: This comprises how the player would respond to or play the game.
3. *Supervision*: This specifies how much supervision a player needs, and in what way.
4. *Feedback*: This is provided to players to not only guide them in right direction but also to tell them how 'correct' or 'well' they have been performing actions.
5. *Evaluation*: This has two aspects—evaluation of the game and its content by the players; evaluation of the players based on their performance and outcome.
6. *Reward*: *S*pecifies how players are rewarded, as reward is a motivational factor.

See the components column in Table 85.2 for elaboration of parameters.

Table 85.2 Evaluation of DBox against the parameters in the framework

Sl. no.	Components	Dependence on other variables/factors	DBox 1.0	Room for improvement
1.	**Information structure and delivery**			
1.1	Formulation of Instruction/ information			
1.1.1	Instruction regarding each sub-steps in the design thinking process		G	
1.1.2	Information regarding any new methods, pertaining to any step		G	
1.1.3	Use of examples		G	
1.1.4	Use of analogies		A	Analogies would help learners make sense of what is to be learned, but are not given in some of the steps.
1.1.5	Use of a storyline	Player's characteristics (age, attitude)	P	Storyline would make the content more interesting
1.2	Sequencing information (order in which instruction/ information is delivered)			
1.2.1	Order of delivery of instruction as per design thinking process		G	

(continued)

Table 85.2 (continued)

Sl. no.	Components	Dependence on other variables/factors	DBox 1.0	Room for improvement
1.2.2	No access to future instructions without the completion of present one		A	In the present scenario, supervision of players is required (to permit no access). Design of delivery of instructions needs a relook.
1.2.3	Access to instructions (directed as per rules):		G: Movement in a board game as per counts in a custom dice provision	Elements can be added so as to maintain curiosity in players at all levels.
1.2.4	Mode of information delivery: Material	Budget/infrastructure	Text on paper	
1.2.5	Mode of information delivery: type		Text + pictogram	Storyboard/images can be used for children
2.	**Response**			
2.1	Flow of tasks		One task per instruction card	
2.2	Nature of output for each step		Notes (text) + tables +/ drawings +/ sketches +/ prototype	
3.	**Supervision**			
3.1	Observing player's task flow	Player's characteristics (aptitude, existing learning, personality)	Required for participants with no serious aptitude	
3.2	Tutoring required	Existing learning	A: Required for new methods/ definition	Content can be more detailed/ self-explanatory so as to cater to novice students.
3.3	Directions/cues required	Player's characteristics	Not likely	
3.4	Choice for supervision		Not given to students	Choice can be provided for more mature student groups
4.	**Feedback**			
4.1	Timing of feedback		Varies; depends on players call	
4.2	Type		G: Creativeness N/A: directional	
4.3	Source of feedback		G: Mentors A: room for self-feedback	Provision for self-feedback should be given to reflect upon players actions
4.5	Medium		verbal	

(continued)

Table 85.2 (continued)

Sl. no.	Components	Dependence on other variables/factors	DBox 1.0	Room for improvement
5.	**Evaluation**			
5.1	Time taken to comprehend instruction	Player's existing learning, information structuring	Varied from 2 min to more than 5 min	
5.1.2	Additional/mentor help required to comprehend instruction	Players existing learning	Yes (in case of new content)	
5.1.3	Player's feedback (based on NASA Task Load Index [22], and system usability scale [23])	Mental, physical, temporal demand, performance, effort, frustration; interesting/curiosity	N/A	Feedback worksheet should be provided to revisit design of content + delivery
5.2.1	Time taken by player to complete a step, level of the whole game	Depends on nature of step + student's ability	Whole game: 4–5 h min	
5.2.2	Difference between the nature of desired output & nature of actual output		Large difference not prevalent	
5.2.3	Relevance of the final output		depends	
6.	**Reward system**			
6.1	Reward in terms of successful completion of the steps		A	
6.2	Rewards in terms of a 'successful' outcome		G	
6.3	Nature of reward		Verbal appreciation	Rewards in terms of physical/virtual coin/ points can be provided to motivate the players through the process

Legend: '*G,*' '*A,*' and '*P*' indicates that IISC DBox fared 'Good enough,' 'Average,' and 'Poor' respectively against the listed parameters. *N/A* not available

85.4 IISC DBox

The gamification model and learning approaches identified have been combined, and a new game was designed by the authors for the purpose of use for design thinking education for children. 'IISC DBox' is a self-contained game for supporting design thinking and design-led innovation. The word 'IISC' is an acronym for 'Identify-Ideate-Select-Consolidate'—the four major steps of design thinking in our model—so that a player can employ design thinking in order to internalize innovation. 'IISC' is also an acronym for 'IISc Innovation Support for Children,' where 'IISc' is the acronym commonly used for **I**ndian **I**nstitute of **Sc**ience,

Bangalore. The game is adaptable to be played at multiple levels of depth and complexity, allowing it to be tuned to various levels of formal education at schools, colleges, and university programs. As a person or a team plays the game, it should train them in design thinking, in the process opening them up to the variety of problems people face as well as how their knowledge from other areas of the education program can be blended with their creativity to help solve these problems. Further, the process should encourage both thinking and doing, seeing these as complementary skills in real-life problem finding and solving.

IISC DBox consists of six major components—level boards, instruction cards, a customized dice, a marker coin, an evaluation sheet, and a feedback sheet.

(1) *Level boards*: There are four level boards in the game pertaining to the four levels of the design thinking process, as mentioned in Sect. 85.3. Each board has 16 positions through which a coin would be traversed by a player. Each position on a board has a color code and a logo. The logos are indicative of the sub-steps of that level of design thinking.
(2) *Instruction cards*: These elaborate on the sub-steps of the design thinking process. The description bears instructions for the players, along with examples or analogies, thus educating players the process. Each card has a color coding and a logo on one side (matching those in corresponding positions of the level board) and text with instructions on the other. The game can have a total of 16–64 cards, depending on the version for less or more experienced players.
(3) *Customized dice*: The dice has four black and two white faces (i.e., a random number generator), which is used to guide motion of the coin along a black or a white pathway. The pathways connect individual positions on the boards. When a player gets a black face on the dice, she can move along a 'black' path, leading to another position on the board, drawing another instruction card, and so on.
(4) *Marker coin*: The coin holds the position of the player on the level board; its motion depends on the dice roll and the availability of pathways on the board. The goal of the player is to traverse each board, while playing the maximum number of instruction cards and maximize the points scored in these steps.
(5) *Evaluation sheet*: This document contains a questionnaire for evaluators to evaluate the performance of the players, after the game is completed.
(6) *Feedback sheet*: A questionnaire the players fill to document how they performed, and difficulties faced; this is used to improve the game in later versions.
(7) *Miscellaneous items*: Include sketchbooks, worksheets with guidelines on which the players document outcomes from the design thinking steps.

The rules of the games are as follows. Each player keeps a marker coin at the start position of the first level board. The player then rolls the customized dice. Depending on the color on the top face of the dice, the player moves the coin along the same colored path, leading to another position. Based on the graphics printed on a position, the player takes out an instruction card, bearing the same graphic, from a set of cards. The player carries out the task described by the instructions on the card

drawn and fills up a worksheet with notes, sketches, and calculations etc., as outcomes from the tasks. After the worksheet is filled, the player rolls the dice again and moves the marker coin along a 'legal' path to the next position. The player continues the moves and associated tasks till the end of the level board is reached. After the finishing the first level board, the player starts the same process for the next level board, till the whole game is finished.

The game is to be supervised by a mentor. The mentor's role is to primarily supervise the player's activity and assist them if they face any problems. The mentor's role is limited to provide explanations of the steps if asked' and is not meant to help with the tasks or solutions for the players or propose mentor's ideas to the students.

85.5 Evaluation of Proposed Design Thinking Model

The first version of IISC DBox was tested at a school in Bangalore in July 2017. About 40 students, divided into 6 groups, from standards 6 to 12 played the game. Each group was composed of students belonging to adjacent standards, in three categories: standards 11–12, standards 8–10, and standards 6–8. No student had prior training in design thinking or methods. Each group was assigned one mentor for supervision. Within a stipulated time of 5–6 h, each group played the game comprising 16 steps and developed a design prototype for solving a problem they identified. The groups observed environments within the school campus (e.g., drinking water area, library, classroom) and generated design solutions. Some examples of the design solutions arrived at are, a stepped water disposal platform to accommodate variable heights of students, increasing seating capacity in their library with enhanced privacy within the same area (Fig. 85.1), etc.

Analysis of IISC DBox 1.0 (the first version of DBox), against the parameters in the framework, is listed in Table 85.2.

Fig. 85.1 Schoolchildren playing IISC Dbox

85.6 Effectiveness and Limitations of IISC DBox

IISC DBox has been reasonably successful in taking the tools and methods of design to students and individuals with little or no prior exposure to design thinking. Since the instructions for the design thinking are modularized into cards and the flow of instructions is guided by the level boards, IISC DBox seems to have the potential for supporting play by a wide range of learners, and at any place. Consolidation of the components of IISC DBox in a kit makes it portable. Playing IISC DBox seems to be a recreational activity for a player enabling an active, self-learning process.

The first version of IISC DBox has several limitations that need to be addressed for a more experiential play and more effective learning. In its current form, the language in the instructional cards is less suited to the general learner. Some of the methods proved to be too technical and complex for the students at the lower standards. Consequently, the role of the mentor transcended from that of a supervisor to more of a tutor. It proved tiring for the players to complete the entire process at a single stretch of time. The game steps appeared more predictable at later levels, but the content of the cards retained the players' interest.

85.6.1 Potential Improvements to IISC DBox 1.0

The next version of IISC DBox could be designed with a personalized storyline for the content so as to make experience specialized for the players. To feel like being an integral part of the game, the players should have an option to choose their avatar. The language in the instruction cards should be simpler, and even vernacular to be more understandable even to novice students. The instruction cards should provide more examples and analogies, to help players internalize design thinking concepts. To check for the overall quality of the output, evaluation should be done at the end of each level. To motivate users till the end of the game, tangible rewards can be given to players based on their performance. These improvements should help IISC DBox transcend from its current, structural level to that of content gamification.

85.7 Conclusions and Future Work

For learning design thinking and methods, it is important for the learner to not only know the overall philosophy behind design thinking but also the right tools and methods, and necessary information for facilitating the design process. A 'gamified' version of design thinking model presented in this paper, aimed at teaching design thinking to schoolchildren, engaged students to learn and understand design

thinking in a step-by-step manner. The evaluation carried out demonstrates there is room for improvement for IISc Dbox. An online version of the game can avoid physical presence of a mentor, and the game could be monitored distantly and has also the potential to make it accessible to rural and remote areas through Internet. The gamification model of teaching could be extended, with appropriate modifications, for other topics as well, where it is necessary to train the learners a 'specific way of thinking and doing things.'

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