# Strategies for Endogenous Design of Educational Games

Submitted in partial fulfilment of the requirements
of the degree of
Doctor of Philosophy

By:

Sandeep Athavale
Roll No. 144137001

Supervisor (s):
Prof Girish Dalvi


Industrial Design Centre
INDIAN INSTITUTE OF TECHNOLOGY BOMBAY
2020

# Dedicated to

The secret energy, that keeps us alive in the great game of life.

# Thesis Approval

This thesis entitled "**Strategies for Endogenous Design of Educational Games**" by Sandeep Gopal Athavale is approved for the degree of Doctor of Philosophy.

**Examiners**

(Aman Parnami)

(Ravi Poovaiah)

**Supervisor (s)**

(Girish Dalvi)

**Chairman**

(Sridhar Iyer)

**Date:** 15 June 2020

**Place:** IIT Bombay (VC)

# Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words are included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute. It can evoke penal action from the sources, which have not been properly cited, or proper permission has not been taken when needed.

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**Sandeep Athavale**

Name of the student

**144137001**

Roll Number

DATED: 20-June-2020

# Abstract

Educational games have remained more a promise than become a reality in changing the way we learn. Occasionally, a few educational games have gained prominence. However, the 'code' to design educational games that consistently meet the desired goal, of learning through fun, is elusive. A key to unlock the potential of educational games is creation of designs that merge the act of learning and playing. It is best if the player achieves the goal of learning by merely playing the game. Games with 'endogenous' design have the potential to meet this objective.

In endogenous design, game elements are derived from the educational content. However, creating endogenous design is challenging. The commonplace technique of superimposing known gameplay over the educational content will not lead to endogenous design. Superficial integration of content and gameplay, often referred to as 'chocolate-coated broccoli', results in games that are neither educational nor fun. Designers can achieve better integration with appropriate guidance. Unfortunately, research in educational games has focussed less on synthesis of educational games, especially so on endogenous design.

The need for endogenous design has been identified in the current literature, but research has not progressed toward building specific guidance on creating such designs. The aim of our research is to bridge this gap. We identify specific strategies that designers can use to design endogenous games. Our research is guided by a pragmatic approach that the outcomes should be of use in practice, while also adding new knowledge to the domain of educational games.

We chose Design Based Research (DBR) as an overarching research approach because of its focus on practical utility. DBR hints at mining knowledge from the existing practices and improving upon it. Hence, the strategies for design are discovered through the study of design practice. By inviting participants to design endogenous games, we explicate the heuristics they may use in doing so. Using 'think aloud' protocol analysis as a technique for data collection and analysis, several raw strategies are identified. We evaluate, aggregate, compare, categorize, and extend these discovered strategies. The strategies are organized into a process framework using the 'Function Behaviour Structure' approach. This framework, named 'Endogen', is the core contribution of our research.

Exploration and translation are the two primary groups of strategies in the framework, which enable endogenous design. The exploration strategies help in identifying the gameable elements in the content such as actors, objects, movements, events, situations, and more. The translation strategies help in translating the extracted elements into game elements such as mechanics, resources, and gameworld. These two are supported by other strategies for core design, elaboration, and verification, to make the design process complete.

With a focus on practical use, our framework is validated for its utility using a multi-method approach. The validation exercise confirms the utility of the framework in enabling endogenous design. The studies also bring up few shortcomings, some of which are addressed in this thesis. In the end, we enlist issues regarding the adoption of new frameworks and address them in the context of the Endogen framework.

The Endogen framework will benefit educational game designers, academicians, as well as students, in designing effective and enjoyable learning games. Researchers can extend our work in the future by adding newer strategies, applying them across contexts, and in more ways than we can yet imagine.

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# Chapter 1 **Introduction**

This chapter provides the background and overview of our research. It also indicates the overall structure of the thesis.

## 1.1 Background

Educational games have long held the promise of becoming the future medium of learning. Gee [2003] mentions that the potential of educational games is significant, because a large and growing population is familiar with playing games. The persuasive challenges that games present can activate the information-processing faculty of players, as well as improve their concentration span, which is otherwise shrinking. The characteristics exhibited by game players such as persistence, risk taking, problem solving, collaboration, and information search are the key ingredients essential for education in school [Klopfer et al., 2009].

Games create a motivational environment by enabling learning through play. The notion of 'play' here is the leeway offered by games to experiment, fail, learn, and improve in an enjoyable environment detached from the hazards of reality. Crawford [2003] proposes that games are the most natural way of learning as compared to any other medium. His conclusion is based on observations of young ones of mammals, who learn their essential survival skills through playing and not through lectures given by their elders.

Yet, educational games have not achieved their potential. There could be several reasons for the same. Probably, games have not kept pace with changing learning habits. Competing mediums such as online videos have outpaced the ‘game’. The evolution of games into new forms may address this challenge. Developing mini and micro games, which deliver ‘just-in-time’ learning through multiple touch points, is one possible trajectory of evolution.

Overpromising could be the second reason. Proponents of educational games need to acknowledge that games alone do not hold sway over providing effective and enjoyable learning. Animations, books, discussions, enactments, laboratories, movies, museums, and stories can be enjoyable as well as effective in an appropriate context. Games, therefore, should be considered as part of the larger ecosystem of learning than a standalone solution [Habgood and Ainsworth, 2011].

Improper positioning of educational games could be the third reason for underachievement. Games, when positioned as ‘games for something’ often cause a conflict with the voluntary nature of play. Games are played for fun and anything else derived from it is a by-product. School students do not need introduction to games in general, but educational games do not find a place in their repertoire. When teachers and parents introduce these task oriented games, students are likely to qualify them as ‘work’ instead of ‘play’. Educational games, therefore, need to be designed with fun as their primary purpose to compete with entertainment games.

Educational games are at the intersection of playing and learning. Hence, these games demand deep integration of game and content elements. However, a commonly observed lacuna in design is housing educational content inside a game [Gunter, 2008]. Moreover, Prensky [2002], observes that gameplay is almost entirely missing in the online (game-based learning) courses being offered today. He suggests that most of these courses are “deadly dull page turners with titbits of generally boring interactivity and rudimentary Eye Candy”.

Critics often use the term ‘chocolate-coated broccoli’ to describe the character of superficially integrated educational games. Coating educational content with incoherent gameplay is a common pitfall in the design of educational games. By giving lesser importance to content, a game for learning history would appear the same as that for learning geometry. Poor integration between content and gameplay can lead to irritating games that fluctuate between learning and playing. This is the fourth and most significant reason for poor adoption of educational games.

The existence of such flaws in educational games is not surprising because designing games that fulfil the seemingly contradictory functions of fun and serious learning is challenging [Flanagan, 2009]. Intrinsic integration of content with gameplay is vital to addressing this challenge. It has been established that games with intrinsic integration, also termed as endogenous design, are more effective as they harness motivation created by 'play' in the act of learning and vice versa [Habgood et al., 2011].

Educational game players learn the desired topics by riding on the 'flow' generated by the play. In fact, learning to navigate and master the game is an essential component of games that are fun [Gee, 2003]. Games cannot be fun if they do not stimulate the brain to learn and master some skill, strategy, etc. If this mastery over gameplay were to coincide with mastery over the educational topic, educational games would be sought voluntarily. Endogenous design holds one key to addressing this need. However, as we discuss in our literature review later, guidance on creating educational games with endogenous design is lacking. Availability of specific guidance on endogenous design can aid designers in creating effective designs. The focus of our thesis is creating this guidance by discovering strategies for endogenous design.

## 1.2 Motivation and Purpose

The underlying motivation of our work is 'making education interesting', especially for those who are struggling with conventional methods. Existing learning mechanisms such as textbooks and teacher-to-student instruction appear inadequate to engage a cross-section of the millennial population [Eckleberry-Hunt and Tucciarone, 2011]. At the same time, traditional memory-based evaluation methods are proving less useful to test the problem solving, creativity, and application skills of the students. Games-based learning, on the other hand, can be more participative, experimental, and application-oriented.

However, educational games need to address some of the challenges discussed earlier for better adoption. A specific challenge, and the domain of our thesis, is the design of educational games. Synthesis of educational games requires integration of content as well as instructional elements in the gameplay, but past research has largely focussed on instructional elements. There is not much emphasis on content integration besides introducing the two prominent approaches: exogenous design and endogenous design. In endogenous design, the game elements emerge from the content, whereas in exogenous design, content and gameplay are unrelated. Endogenous design creates better motivation as it unifies the acts of learning and playing.

Although broad suggestions to create endogenous designs, such as identifying ‘restructurable’ elements in the content [Deen, 2015], are available, specific guidance is missing [Ke, 2016]. Due to the lack of adequate guidance on endogenous design, designers often create exogenous designs, which require players to deal with learning and playing separately, causing frustration. How can designers be supported in synthesizing games with endogenous design? Our research aims to answer this question by creating guidance on endogenous design. The guidance is about knowing ‘the ways to discover gameness’ in the content and translating it to a playable game. These ‘ways’ are the design strategies of our interest.

Knowing how the ingredients of the content (subject matter) lend themselves to the development of gameplay is fascinating and a matter of intellectual curiosity. Content for every topic offers multiple interesting patterns, constraints, contests, interactions, associations, transformations, visualizations as well as monotony, boredom, complexity etc. Textbooks also have some amount of game structures present in the form of examples and exercises. Figure (1.1), illustrates the notion of identifying such embedded fun structures in the content. Assisting designers in capturing these fun structures, in translating them to appropriate game elements (goals, settings, mechanics, resources etc.), and in creatively binding the translated elements into a game, is the pursuit of our research.

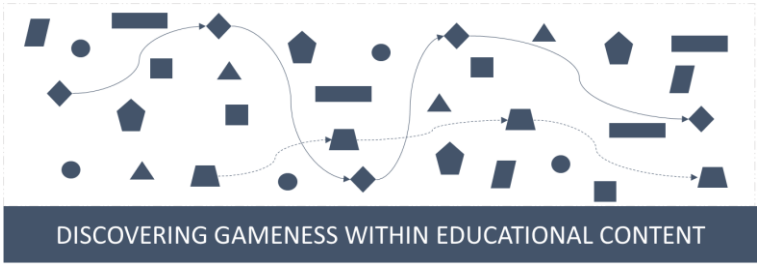



Figure 1.1 Curiosity: Finding Gameness in the Content

## 1.3 Research Scope, Objectives and Approach

The canvas of educational games research ranges from discussing the need for games to evaluation of games in learning environments on one dimension, and from kindergarten to higher studies to adult learning on another. Our work is related to the synthesis of educational games. The focus of our work is identifying strategies for endogenous design as indicated in figure (1.2). The scope is limited to topics from the middle school curriculum (sixth grade to ninth grade). The choice of this segment allows us to discover a foundational set of strategies. Every segment of higher education might require additional design strategies, but we expect that the foundational set will remain at the core.

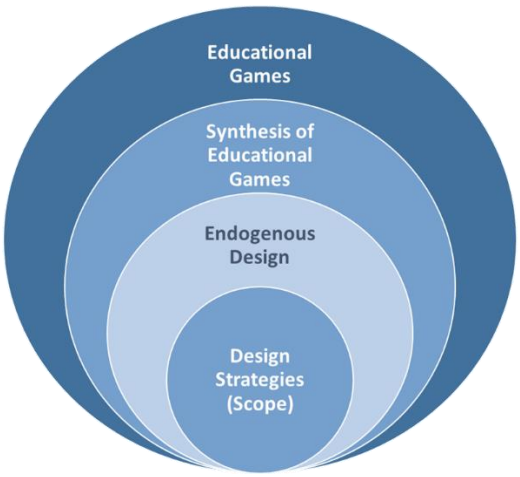



Figure 1.2 Scope of Research

The objective of our research is to generate knowledge in the form of strategies for endogenous design of educational games, and make this knowledge available to designers through a process framework. Design strategies are intended to help designers extract gameable elements within the content, translate them to game elements and integrate the translated elements into a complete game concept. These strategies are compiled into a cohesive framework, named Endogen for easy consumption by students, academicians and professional designers.

Our approach for advancing knowledge on design strategies is through the study of design practice. We used the protocol analysis method for the collection and analysis of data generated during planned design sessions. The studies allowed us to understand how designers apply tacit knowledge in the form of heuristic principles to create games with endogenous design for the topics provided. The analysis and synthesis of aggregate data from various participants led to the discovery of design strategies. These strategies were organized into a framework using the Function Behaviour and Structure (FBS) approach.

## 1.4 Significance of Research

Educational games are yet to realize their potential of being a pervasive educational media. Creating designs that unify the acts of playing and learning can make games compelling to play and thereby to learn from them. Despite decades of work in the field of educational games, designing games that seamlessly integrate playing and learning has remained challenging. Games with endogenous design can address this problem. However, research on developing guidance on endogenous design has not advanced as much. Analysis conducted by several authors, including Bellotti [2010] and Ke [2016], indicate a lack of specific guidance that designers can use.

Designers can do well when supported with specific strategies that can help achieve endogenous design. The significance of our research is in creating new knowledge in the form of design strategies that were hitherto not available to designers. The core contribution of our work is the framework of strategies for endogenous design. This framework enables designers to cover essential aspects of design. It provides step-by-step guidance to novice designers from preparation to verification of design, whereas experienced designers can use select strategies for reference. Game design teachers can also use the framework as a teaching aid.

The framework can also serve as a practical companion for design students. Students can use the framework to learn the process and nuances of educational game design. Our work also opens up a few avenues for future research. The framework can be extended to include strategies for new segments such as higher education, new domains such as behaviour change, as well as strategies that cater to different types of content.

Beyond the immediate and incremental benefits of our research to designers, we believe that the strategies will offer a new approach of learning within the constructivist paradigm. Learners can find interesting elements in the content and toy around with them. Learning can become more self-initiated, participative, active, and experimental as compared to a passive, involuntary reception of information.

## 1.5 Structure of the Thesis

The thesis is organized into six chapters starting with the introduction to the topic (this chapter). Chapter 2 provides a background of educational game design and introduces the concept of endogenous design. Chapter 3 describes our research approach, design and execution with protocol analysis method as its core. This chapter also presents the emergent strategies discovered from the analysis of the data. Chapter 4 focusses on synthesising a framework of strategies using the FBS approach. Chapter 5 discusses the validation of the framework using a multi-method approach and discusses its potential adoption. Chapter 6 concludes the thesis with a summary of findings and limitations and provides guidance for future work.

## 1.6 Core Concepts

The core concepts involved in this thesis are introduced here for ease of reading. These will be discussed in detail in relevant sections.

**Gameplay**: Gameplay is the core movement in the game enabled by the game mechanics.

**Educational Content:** Educational content is the subject matter of the specific educational topic under consideration.

**Endogenous Design:** In the context of educational games, a design, in which game elements are derived from the restructurable elements of the educational content, is termed as endogenous design.

**Conceptualization:** Conceptualization is the first stage in the design process where the idea is generated, shaped, and described. Prototyping and (play) testing are done after this stage. This thesis focuses on the conceptualization stage.

**Design Strategies:** Design strategies are tactics, techniques, methods, steps, and activities employed by designers to achieve design goals.

**Protocol Analysis:** Protocol analysis is a research method in which participants think aloud while performing a design activity. The activity sessions are recorded and analyzed.

**Design Framework:** Design framework is a set of interconnected stages, activities and strategies that provide guidance to designers.

**Player/Learner:** A player is one who plays the game. However, the intention of educational games is to enable learning, therefore, the player is also a learner. In this thesis, we use the terms player/learner interchangeably in the context of educational games.

**User**: The term ‘user’ in this thesis generally signifies user of the design framework.

# Chapter 2 **Educational Games and Endogenous Design**

Educational games are at the intersection of learning and playing. The figure (2.1) depicts the intersecting concepts in three layers: the concepts of learning in the top layer, playing in the middle layer and the intersection between them in the bottom layer. The first two columns indicate the consumer role and goal. The last two indicate the role of designers and their mechanism to meet the goal. The dotted box indicates the domain of interest for this thesis.

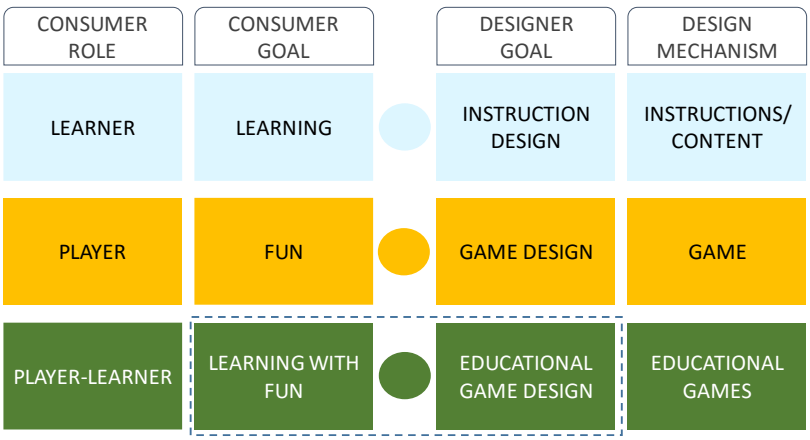



Figure 2.1 Domain of Interest

This chapter discusses the foundational concepts, in the fields of education and games that are required to appreciate educational game design. This chapter also presents the state of research on educational game design and identifies the gaps relevant to our research. Finally, the concept of endogenous design is discussed in detail.

## 2.1 Games and Educational Games

Understanding the concept of game is easy, but defining it is not. Since people understand games without defining them, it may not even be necessary to define them [Wittgenstein, 2009]. However, to build newer knowledge of a subject, it is essential to start with a common baseline and hence the definition. Games have been defined by authors [Suits 2014, Crawford 2003, Sutton-Smith 2009] in several ways, each definition having its own inclusions and exclusions of essential characteristics of games. Salen et al. [2004] have analyzed some of these definitions and defined a game as "a system in which players engage in an artificial conflict, defined by rules that result in a quantifiable outcome". This definition indicating the game to be a system of components is useful for the synthesis of several components that make up a game.

The game system, however, should not be construed as a digital system alone, because games do not merely imply digital or video games. Though there is a tendency to associate games and especially educational games with the digital medium, this thesis embraces games of all kinds: physical, table-top, and digital. Within the game systems, this thesis focuses on systems of structured play. Callois [2001] makes a distinction between structured play (games) and unstructured play (or just play). While both can support learning, the role of the designer, and therefore the value of design strategies is prominent in structured play whereas less prominent (or missing) in unstructured play.

### 2.1.1 Educational Games

Humans have used games to hone skills required for survival from the times of the hunter-gatherer. The young ones of a few mammals can also be observed playing games to hone such skills. It can therefore, be possibly inferred that the games came into being for learning. However, in the case of humans, when survival skills shifted from physical to mental, different mechanisms of education became prominent and games were relegated to the function of amusement. For most of the 20$^{th}$ century, learning was supposed to be serious hard work and games were not considered as a serious option in that scheme other than for training physical skills, in the military, and in strategy-making. In late the 1900s, after the advent of new educational theories, educational games came back to the fore. They were considered a promising augmentation to text book learning. Games have a unique role in learning because they offer interactivity, unlike books, videos, and animations.

James Gee [2003] argues that learning is an inherent part of every game. However, the purpose of all games is not to impart learning. Most games are simply for entertainment. Games having a purpose in addition to entertainment are called serious games [Abt, 1987]. These games, also known as purposeful games or applied games can have varied purposes such as education, problem solving, information dissemination, promotion of wellbeing etc. Educational games represent a subset of serious games. Games that are explicitly designed for learning a concept/skill/behaviour without compromising on entertainment can be termed as educational games. It is important to note that entertainment, amusement or enjoyment remains an essential part of serious games, whatever be their purpose. Educational game design needs to be cognizant of the psychological foundations of learners, which include the cognitive, motivational, affective, and sociocultural perspectives to achieve their potential for learning [Plass et. al 2015].

Simulations and gamification are close relatives of serious games. However, they are different concepts and it is essential to differentiate between them. Simulated systems are replications of real-world phenomenon in the virtual world, and can be used for educational purposes. Simulations are not games, but they can be converted to games by adding game elements [Prensky, 2001]. Similarly, gamification is different from games. Gamification implies embedding game elements into the real-world context. Gamification is distinct from games because there is no magic circle (artificial world) wherein players voluntarily participate to play. Gamification can be used to gamify an educational process through rewards and badges; however, it does not make up an educational game. The continuum of games - serious games - simulations - gamification can be presented on the real-artificial axis as shown in figure (2.2)

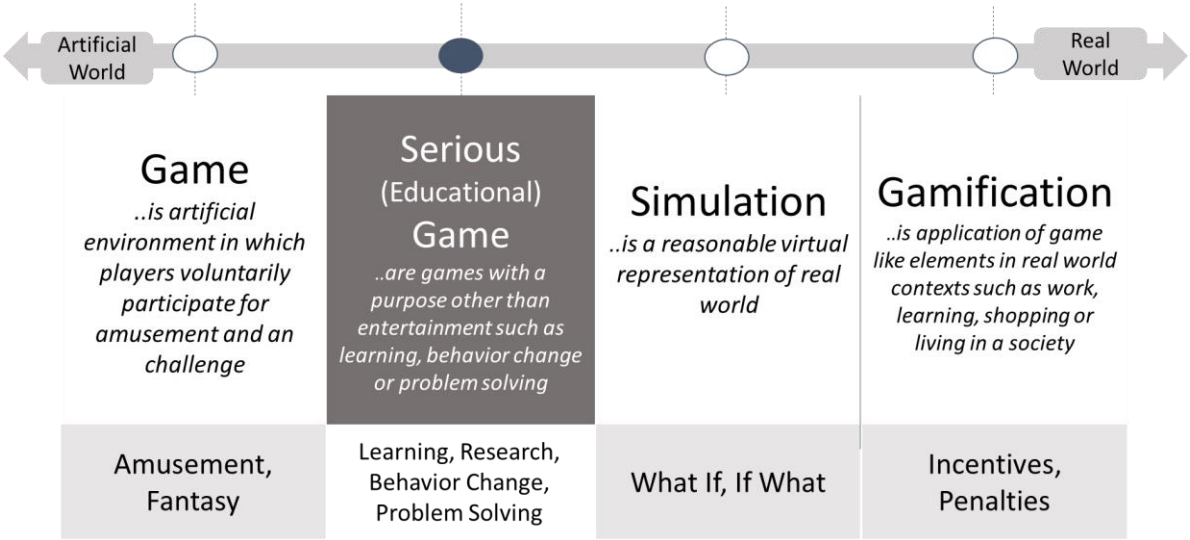



Figure 2.2 Games, Serious Games and Gamification

## 2.2 Designing a Game

It is possible for almost anybody who has played a game to design a new or modified game. Players do that all the time. However, systematic knowledge of the structure and components of a game can significantly enhance the quality as well as the completeness of the design. Additionally, educational game design requires an understanding of the ways in which content can be integrated into the game. The key concepts essential to make informed decisions towards the design of an educational game are discussed in this section.

### 2.2.1 Game System

A game system similar to any other system is made of interconnected components and elements. Besides the popular three-part MDA (Mechanics-Dynamics-Aesthetics) structure proposed by Hunicke et. al [2004], several authors [Jarvinen 2008, Schreiber 2009] have attempted to deconstruct the game system into elements and atoms. Zagal et. al [2007] have created an ontology of game elements. Agrawal and Athavale [2017] scrutinized these resources and created a unified model of a game system, as indicated in figure (2.3). The model depicts a game as a system of components and interconnections. The key components include the game mechanics, dynamics, resources, and the methods/tools/choices for player interaction. Each component has further subcomponents and elements, not depicted in the figure. This model is used a reference for game components throughout the thesis.

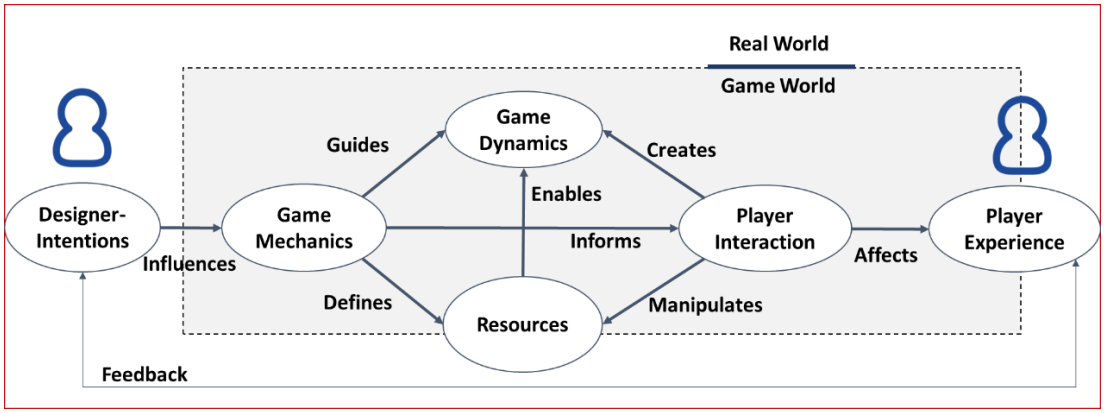



Figure 2.3 Unified Model of Game System [Agrawal, Athavale]

To avoid any ambiguity of terms, specific definitions of game mechanics and dynamics are adopted for this thesis. Game mechanics are defined as the methods invoked by agents (players and or system) for interaction with the game state [Sicart, 2008]. The definition of game dynamics is borrowed from Hunicke et. al [2004]. Accordingly, game dynamics is defined as the run-time behavior of the mechanics acting on player inputs over time. Game dynamics can also be viewed as a state diagram with a series of game states modified by players or the system.

### 2.2.2 Gameplay

Gameplay is a commonly used term by players and designers alike. However, there is very little agreement on what exactly it is. Rollings and Adams [2003] define gameplay as a synergy emerging from the interaction of certain elements included in the game, whereas Fabricatore [2007] defines gameplay as the set of activities that can be performed by the player during the ludic experience. Each of these definitions has different perspective and scope. These definitions, however, do not explicitly include the notion of 'movement', which is key to progress in a game and responsible for the overall experience of the gameplay. *We define gameplay as the movement in the game enabled by a combination of core and opposition game mechanics*. Gameplay is closer to game dynamics in terms of movement, but not the same, because dynamics is a continuous change of state of the system, whereas gameplay is the players' control and experience of the movement in the game.

### 2.2.3 Game Design Process

There is no universally accepted game design process, however, several authors agree on the generic stages. Since game design belongs to the discipline of design, the design process in general such as the Divergence-Transformation-Convergence approach [Jones, 1992], can as well be adopted for the game design. Dukes [1974], has defined a circular design process consisting of Design, Construct, and User Phases. Fullerton [2018] has described the game design process with broad stages such as Conceptualization, Prototyping, Digital Prototyping (if the game has a digital version), Playtesting and Verification (of completeness, balance, fun etc.). Figure (2.4) indicates the stages and sub stages of the process.

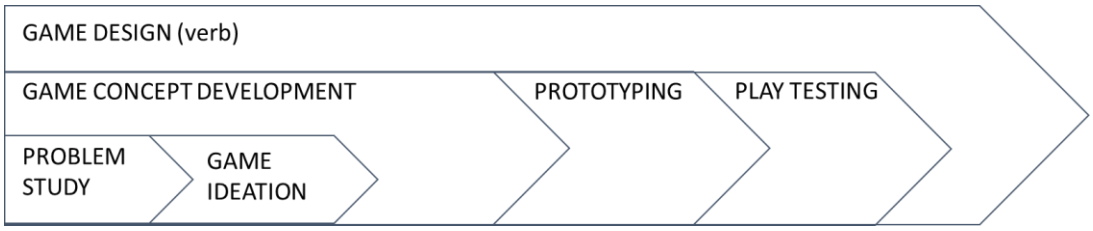



Figure 2.4 Generic Game Design Process

Educational game design being a subset of game design, the generic process applies to it. However, educational game design being more specialized than generic game design; it will have additional stages/steps of its own. Few authors have proposed specific educational game design processes as well. For example, Amory [2007] has suggested a Game Achievement Model (GAM) as indicated in figure (2.5). The process indicates broad steps particularly suitable for digital games.

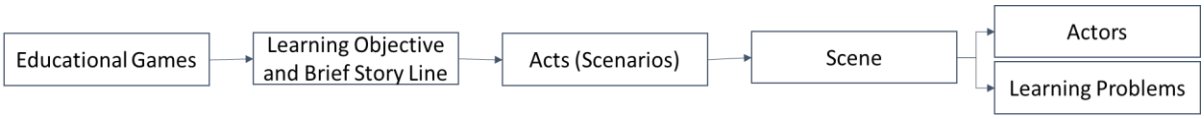



Figure 2.5 Educational Game Design Process [Amory]

However, a process such as GAM presents a one-dimensional view that remains agnostic to the type of content or learning objectives. These processes do not articulate specific design strategies. A design process that elaborates these details need to be developed and our thesis attempts to do so.

### 2.2.4 Conceptualization

Conceptualization or concept development is a key step of any design endeavour and as much in game design, however, it has not been given due attention in research. Among the few works, Hagen's study on game ideation [Hagen, 2004] indicates that creation of a new game concept generally consists of two parts: the recycled part and innovative part. The recycled part consists of ideas that have been used in earlier games, movies, books etc., and the innovative part consists of original ideas. This ideation approach applies to educational games as well. In educational games specifically, ideas generated from the content are essential to create endogenous designs. However, literature on such ideation based on educational content is missing. Athavale and Mohan [2018] studied the ideation process of several participants in an educational game design competition to identify any content-lead ideation but reported inadequate use of content elements in the creation of game concepts.

Game ideation is largely a creative process due to lack of 'player' requirements and has fewer constraints, as compared to product design, which is largely a rational process generally driven by user requirements [Tschang and Szczypula, 2006]. However, in educational game design, there can be a 'learner' requirement. Educational game design would therefore require a combination of creativity and rational/systematic approaches.

## 2.3 Facets of Learning

Defining 'learning' is a challenge similar to defining games, as there are several definitions. Different schools of thought namely behaviorism, cognitivism, and constructivism [Ertmer and Newby, 1993] inform us about the different lenses used to understand learning. These definitions, approaches to learning, types of content, and relevant instructional design approaches are discussed in this section.

### 2.3.1 Theories and Methods

Learning is an observable behavior change according to the behaviorist school of thought. It is concerned with a stimulus-response and does not account for internal cognitive processes of the mind. In behaviorism, learning is achieved through reinforcement and is accomplished when the subject demonstrates a proper response to a stimulus. However, the school of cognitivism rejects behaviorism and instead suggests that learning is a mental process. In cognitivism, the focus is on how information is received, organized, stored, and retrieved by the mind. Learning is concerned with what learners know.

The third school, constructivism, propounds a theory that equates learning with creating meaning from experience. Though constructivism is a branch of cognitivism, the difference is in the way knowledge is created. In cognitivism, learning is through knowing the facts about the world while in constructivism it is about making one's own interpretations. The idea that people make sense of their experiences is in particular emphasized in Kolb's learning cycle [Kolb, 2014], which is based on Dewey's learning-by-doing philosophy [Dewey, 1986]. This paradigm is sometimes also called 'personal constructivism' (to separate it from 'socio-constructivism'). Socio-constructivism extends constructivism by adding the dimension of socio-cultural learning. It posits that knowledge is socially constructed and negotiated in a process involving multiple people.

Papert and Harel [1991] introduced another school of thought to learning called constructionism. The constructionist way learning is through active creation of artefacts of social relevance. It is similar to constructivism in terms of 'learning by doing', but it is different in the sense that the learning is not instructionist and is created rather than transmitted.

Hall [2015] indicates that educational games can be used to facilitate a number of different pedagogical approaches such as constructivism, constructionism, and situated cognition. Further games can also facilitate learning through deduction, hypothesis testing, and visual-spatial processing. Games are, however, generally suited for the constructivist learning approach. Games can also support the constructionist paradigm when students make their own games. In the constructionist approach, students can construct new relationships with knowledge rather than embedding 'lessons' directly in games [Kafai, 2001]. The strategies discovered through our studies can support one or more paradigms, however, they are better suited for the 'embedding' and hence constructivist approach.

### 2.3.2 Content Classification

Does the difficulty or the approach to educational game design change with different type of topics? To know the answer, we studied prior work on classification of content. We found the Anderson-Krathwohl matrix [Anderson et al., 2001], an extension of the Component Display Theory [Merrill, 1983] as a useful classification system for our work. The matrix as shown in figure (2.6) represents cognitive levels based on Bloom's taxonomy on one axis and knowledge dimensions or categories of the content on the other. The cells represent the learning objectives. Among the four categories (Factual, Conceptual, Procedural and Metacognitive) presented by the authors, we have considered the first three.

| | **Remember** | **Understand** | **Apply** | **Analyze** | **Evaluate** | **Create** |
|---|---|---|---|---|---|---|
| Factual Knowledge | *Objective 1* | | | | | |
| Conceptual Knowledge | | *Objective 2* | | | *Objective 3* | |
| Procedural Knowledge | | | | | | *Objective 4* |

Figure 2.6 Content Classification [Based on Anderson and Krathwohl, 2001]

There are other classification systems as well. Kraiger et. al [1993] proposed a classification of content based on skill, cognition, and affect. The cognitive category further includes declarative (factual), procedural and strategic content. Comparing the two, skill, affect and strategy do not find a place in Krathwohl's matrix, whereas conceptual category is missing in Kraigers. However, we restricted ourselves to the three categories indicated in figure (2.6) as it sufficed for topics from the curriculum. It was recognized that classifying a topic neatly into one category is not easy due to overlap. For example, the topic of 'Heat' in Physics has mainly conceptual elements but also some procedural elements. In such cases, we decided to classify the topic based on the prominence of type of content.

### 2.3.3 Instructional Design

Instructional design strategies aid designers to device methods, tools and structures to instruct learners effectively. Instructional strategies can inform the educational game design strategies, and hence a brief review of instructional strategies is relevant. Significant work on instructional design has been done by Gagne and Briggs [1974] who propose nine events/stages of instruction and methods to achieve each stage as indicated in table (2.1). The methods are akin to strategies that educational game designers can draw from. Keywords are shown in italics in the table to indicate that they are potential candidates for reuse as game design strategies.

Table 2.1 Stages of Instruction [Gagne]

| **Event** | **Methods** |
|---|---|
| Gain attention of the students | Motivate students with *novelty*, uncertainty and *surprise*, Pose thought-provoking questions. |
| Inform students of the objectives | Describe required performance. |
| Stimulate recall of prior learning | Ask *questions about previous experiences* and understanding of previous concepts. |
| Present the content | Organize and chunk content in a meaningful way. Provide explanations after *demonstrations*, present vocabulary, provide examples, present content in multiple modes, e.g., video, demonstration, lecture, group work. |
| Provide learning guidance | Provide instructional support as *scaffolds (cues, hints, prompts).*<br>Use varied learning strategies – concept mapping, *role-playing, visualizing.*<br>Use *examples and non-examples*, advice students of resources available.<br>Provide case studies for real world examples, *analogies* for concept building, *visual images* to make visual associations. |
| Elicit performance (practice) | Promote student activities – ask questions, build on what students already know or *make students collaborate with their peers.*<br>Promote recall strategies – ask students to *recite, revisit, or reiterate* information they have learned.<br>Facilitate the students to elaborate. |
| Provide feedback | *Confirmatory feedback*<br>*Corrective and remedial feedback*<br>*Informative feedback* – Provides information (new, different, additions)<br>Analytical feedback –suggestions, recommendations |
| Assess performance | Pretest and post-test for mastery of prerequisites.<br>Embed questions throughout instruction through questioning and/or *quizzes*<br>Include objective performances - *measure how well a student has learned*<br>Identify *comparative performances* between students. |
| Enhance retention and transfer to job | Create job-aids, references, templates, or wizards, *application scenarios* |

The summarization of keywords in the table indicates features such as novelty, surprise, visualization, metaphorical representations, quizzes, scenarios, avenues for collaboration, pro-con choices, hints, role-play, repetition (through use of mechanics), feedback and measurement (through game score and possessions). These features can naturally form a part of the game system. There are other relevant instructional design models such as ARCs model for instructional design [Keller, 1987], but the analysis of these do not yield significantly different keywords. Educational game researchers have created mappings between instructional strategies and game design, which we discuss in subsequent section.

## 2.4 Intersection – Learning through Games

Educational games are at the intersection of learning and games. It may be stating the obvious but essential. This space has been densely populated with research coming from both educationists and game designers. Several attempts have been made to create educational games for specific topics and to evaluate their effectiveness in specific settings. A few authors have studied the ways to integrate learning and games to propose integration models. The extent of research in this space has warranted few meta-analyses as well, for example, Wilson et al. [2009] conducted a meta-analysis of mappings of learning attributes and game elements to report the prominent as well as missing mappings. In this section, prominent integration models are discussed to understand the current state of the knowledge and the gaps therein.

Figure (2.7) indicates the range of literature we surveyed to identify the design practices, models and techniques for educational game design. The search is on two planes: game design in general on the top and educational game design on the bottom plane. The arrows indicate the direction of the search and the dotted arrows indicated the limited work, or gaps in the space.

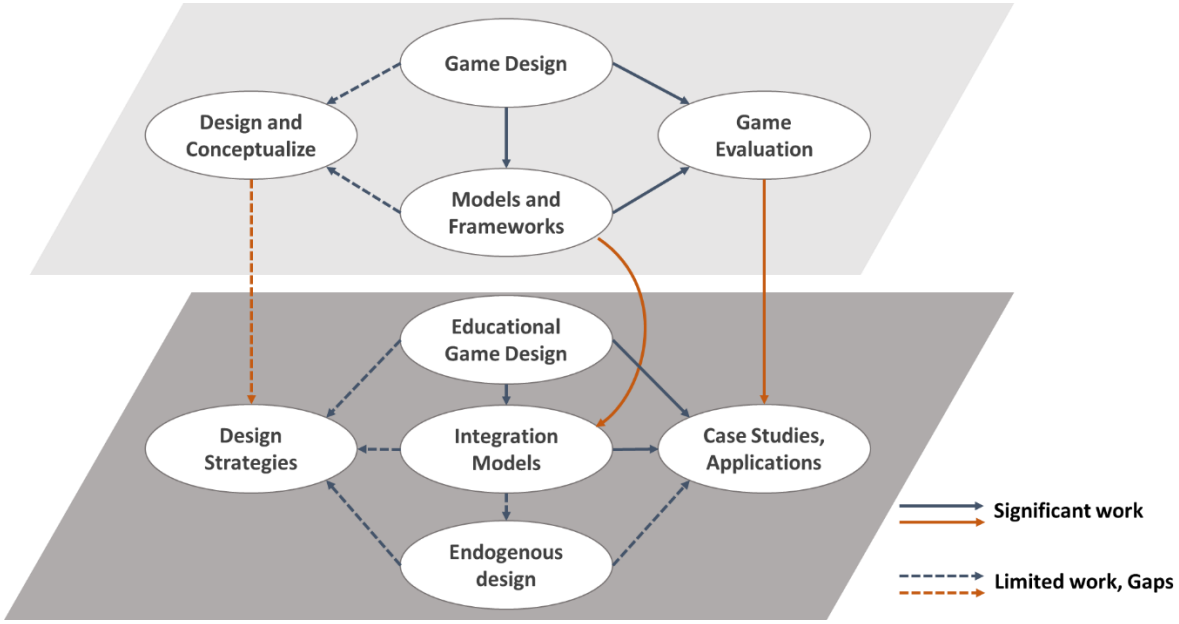



Figure 2.7 Literature Review Summary

In the game design space (top layer), there are several models, frameworks and ontologies that describe the game system. In addition, there is literature on evaluation using instruments such as enjoyment questionnaires as well as approaches such as playtesting. The analysis of several papers on game-based learning (bottom plane) informs us that literature is rich in a) models for macro integration of learning with game elements, b) evaluation methods to evaluate the effectiveness of games, and c) case studies that attempt design of games for specific topics.

Game-learning integration models are mainly of two types: mapping models and process models. Mapping models attempt mapping of learning structures (paradigms, methods, instructional strategies, learning attributes, content types) with game elements. Process models guide the designers through a process to carry out integration. Within the literature on integration models, research on endogenous design is limited. Literature on game synthesis, conceptualization and design strategies is, in general, sparse.

### 2.4.1 Mapping Models

**Learning Paradigms to Type of Game**

In her article 'Can Educational Be Fun', Bruckman [1999] mentions the term 'chocolate dipped broccoli' to indicate a design approach in which the educational content is coated with a layer of game. She argues that learning can be inherently fun, but such approaches depict learning as a bitter pill that needs to be consumed with sugar. To overcome such lacunae, she suggests the use of approaches based on constructivism and constructionism rather than the drill and practice approach of behaviorism. Table (2.2) shows the mapping between the learning paradigm and the type of game it supports. This mapping informs designers to avoid drill and practice games but does not inform how the inherent fun elements in the content can be translated to puzzles or other games that support constructivism.

Table 2.2 Mapping Learning Paradigm to Game Type [Bruckman]

| **Learning Paradigm** | **Type of game** |
|---|---|
| Behaviorism | Drill and Practice |
| Constructivism | Puzzles |
| Constructionism | Construction Kits |

**Instructional Design to Game**

In concurrence with Bruckman's suggestion, Gunter et al. [2008] advise that pouring educational content into a game is a bad idea. A good educational game requires a combination of the semiotics and context for entertainment as well as for education. According to them, design of educational games should be based on well-established instructional theories. The authors provide a mapping of instructional design elements with game elements, as indicated in figure (2.8). The instructional elements are derived from the Gagne events and Kellers ARC model. The authors also propose a 'RETAIN' model, which can act as guidance for design. It can also serve as a rubric for the evaluation of educational games. Though their mapping is useful for macro design decisions, it does not guide on embedding content into the gameplay.

| Gagne's Nine Events | Keller's ARCS Model | Common Game Elements |
|---|---|---|
| Gain Attention | Attention | Scenario Exposition |
| Inform of Objectives | | Problem Setup |
| Stimulate Recall | Relevance | *No existing game analog* |
| Present Stimulus/Lesson | | Offer Challenge/ Choice |
| Provider Learner Guidance | Confidence/Challenge | Provide Direction |
| Elicit Performance | | Elicit Action/Decision |
| Provide Feedback | Satisfaction/Success | Discernable Outcome |
| Assess Performance | | Success/Failure Screens |
| Retention and Transfer | | *No existing game analog* |

Figure 2.8 RETAIN Mapping Model [Gunter et al.]

**Pedagogy to Game Elements (Game Object Model)**

Amory [2007] proposes a couple of versions of the Game Object Model (GOM) for designing serious/educational games. He presents a relationship between the pedagogical dimensions of learning and game elements. Object-oriented modelling inspires the structure of GOM. The model has a hierarchy of spaces for game elements, visualization elements, and learning elements. Each space has methods/interfaces to conceptualize digital games. Though this model presents an arrangement of relevant concepts, it can be difficult to use in practice. This model does not delve into the integration of content.

**Learning Mechanics to Game Mechanics (LM-GM)**

Arnab et al. [2015] propose a LM-GM model as reproduced in figure (2.9).

| GAME MECHANICS | THINKING SKILLS | LEARNING MECHANICS |
|---|---|---|
| ○ Design/Editing<br>○ Infinite Game play<br>○ Ownership<br>○ Protégé Effect<br>○ Status<br>○ Strategy/Planning<br>○ Tiles/Grids | CREATING | ○ Accountability<br>○ Ownership<br>○ Planning<br>○ Responsibility |
| ○ Action Points<br>○ Assessment<br>○ Collaboration<br>○ Communal Discovery<br>○ Resource Management<br>○ Game Turns<br>○ Pareto Optimal<br>○ Rewards/Penalties<br>○ Urgent Optimism | EVALUATING | ○ Assessment<br>○ Collaboration<br>○ Hypothesis<br>○ Incentive<br>○ Motivation<br>○ Reflect/Discuss |
| ○ Feedback<br>○ Meta-game<br>○ Realism | ANALYSING | ○ Analyse<br>○ Experimentation<br>○ Feedback<br>○ Identify<br>○ Observation<br>○ Shadowing |
| ○ Capture/Elimination<br>○ Competition<br>○ Cooperation<br>○ Movement<br>○ Progression<br>○ Selecting/Collecting<br>○ Simulate/Response<br>○ Time Pressure | APPLYING | ○ Action/Task<br>○ Competition<br>○ Cooperation<br>○ Demonstration<br>○ Imitation<br>○ Simulation |
| ○ Appointment<br>○ Cascading Information<br>○ Questions And Answers<br>○ Role-play<br>○ Tutorial | UNDERSTANDING | ○ Objectify<br>○ Participation<br>○ Question And Answers<br>○ Tutorial |
| ○ Cut scenes/Story<br>○ Tokens<br>○ Virality<br>○ Behavioural Momentum<br>○ Pavlovian Interactions<br>○ Goods/Information | RETENTION | ○ Discover<br>○ Explore<br>○ Generalisation<br>○ Guidance<br>○ Instruction<br>○ Repetition |

Figure 2.9 LM-GM Mapping Model [Arnab et al.]

They have extracted game mechanics from the literature on game studies and pedagogical elements from learning theories. These elements are mapped using Blooms taxonomy as a glue. This model is better suited for evaluation or analysis of games. During synthesis, this mapping can be used to translate some instruction design principles to game elements. However, this mapping also does not aim to suggest ways to integrate elements of content into gameplay.

**Type of Content to Game**

Prensky's mapping of content and game styles [2001] is the only one that considers the content type as a factor in mapping, but with type of games. The mapping is reproduced in figure (2.10).

| "Content" | Examples | Learning activities | Possible Game Styles |
|---|---|---|---|
| Facts | Laws, policies, product specifications | questions<br>memorization<br>association<br>drill | game show competitions<br>flashcard type games<br>mnemonics<br>action, sports games |
| Skills | Interviewing, teaching, selling, running a machine,<br>project management | Imitation<br>Feedback<br>coaching<br>continuous practice<br>increasing challenge | Persistent state games<br>Role-play games<br>Adventure games<br>Detective games |
| Judgment | Management decisions, timing, ethics, hiring | Reviewing cases<br>asking questions<br>making choices (practice)<br>feedback<br>coaching | Role play games<br>Detective games<br>Multiplayer interaction<br>Adventure games<br>Strategy games |
| Behaviors | Supervision, self-control, setting examples | Imitation<br>Feedback<br>coaching<br>practice | Role playing games |
| Theories | Marketing rationales, how people learn | Logic<br>Experimentation<br>questioning | Open ended simulation games<br>Building games<br>Constructing games<br>Reality testing games |
| Reasoning | Strategic and tactical thinking, quality analysis | problems<br>examples | Puzzles |
| Process | Auditing, strategy creation | System analysis and deconstruction<br>Practice | Strategy games<br>Adventure games |
| Procedures | Assembly, bank teller, legal | imitation<br>practice | Timed games<br>Reflex games |
| Creativity | Invention, Product design | play | Puzzles<br>Invention games |
| Language | Acronyms, foreign languages, business or professional jargon | Imitation<br>Continuous practice<br>immersion | Role playing games<br>Reflex games<br>Flashcard games |
| Systems | Health care, markets, refineries | Understanding principles<br>Graduated tasks<br>Playing in microworlds | Simulation games |
| Observation | Moods, morale, inefficiencies, problems | Observing<br>Feedback | Concentration games<br>Adventure games |
| Communication | Appropriate language, timing, involvement | Imitation<br>Practice | Role playing games<br>Reflex games |

Figure 2.10 Content to Game Type Mapping [Prensky]

The mapping depicts the way the knowledge dimensions of Anderson et al. [2001] can be addressed by different types/styles of games. This mapping provides initial decision support for endogenous design but does not help in translating the content to game.

**Play, Pedagogy, and Fidelity Triadic Framework**

Rooney [2012] explores the triadic relationship between play, pedagogy, and fidelity. Unlike previous models, which map two dimensions, this model brings a third dimension in the form of fidelity. Fidelity is indeed an essential aspect of educational games. Game designers strive to stretch the limit of reality while they are expected to remain truthful to the content. Rooney brings out the complexity in designing a coherence between these contesting dimensions. The proposed endogenous design framework will need to be cognizant of the fidelity/authenticity dimension.

### 2.4.2 Process Models

**Input Process Outcome Model**

The 'Input-Process-Outcome' model in figure (2.11) indicates that insertion of instructional content and game characteristics into a game cycle can generate the intended learning outcomes [Garris et al, 2002]. The central aspect of this model is the iterative game cycle, in which the users are actively engaged for constructing knowledge. It is akin to Kolb's learning-by-doing model [2014]. Though this model takes instructional content as input, it is not integrated with game elements. The game characteristics are used only as triggers for learning.

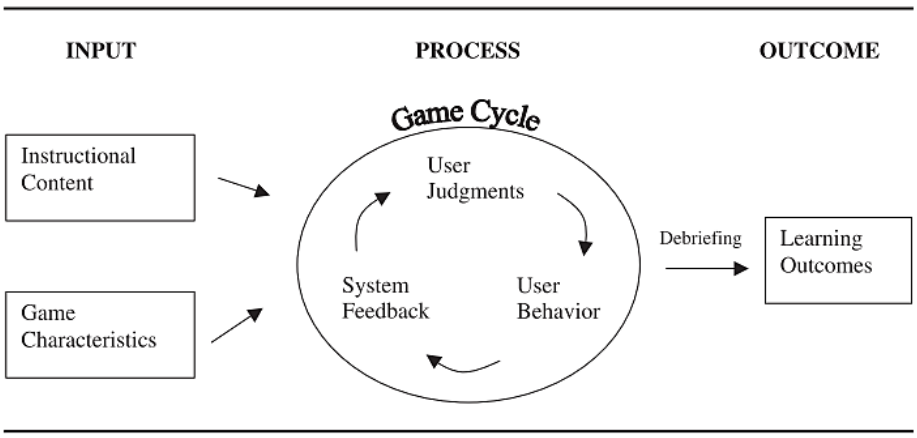
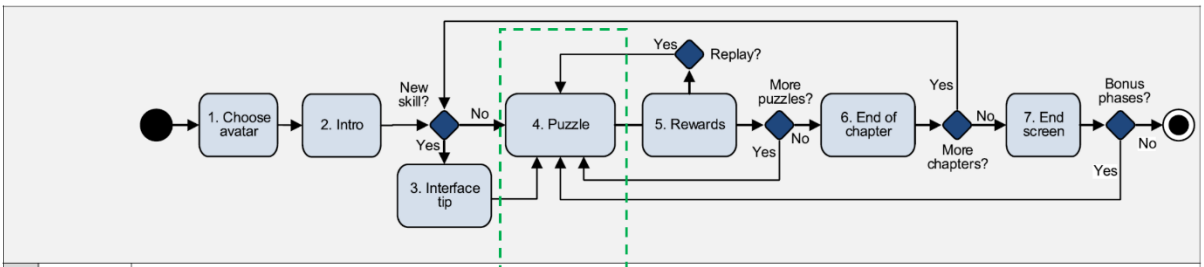



Figure 2.11 Input-Process-Output Model [Garris et. al]

**Activity Theory Based Model**

Carvalho et al. [2015] proposed an activity theory-based model for serious games analysis and design. The model, reproduced in figure (2.12), provides an actionable process for designers. The authors provide specific questions that designers must address in every cell/step of the design. They act as guidance for synthesis. The model aids in linking game and pedagogic components. There is a step of intrinsic instructions, which can enable endogenous design, but the only advice for designers is to design puzzles (refer dotted box). The approach to design content-specific puzzles or games remains unanswered.




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Gaming | Actions | Customization | Watch | Obtain help | Matching | See performance evaluation | See performance evaluation |
| | Tools | Avatar | Information | Tutorial | Tiles; Performance Meter; Warning messages | Rewards; Performance meter | Rewards; Levels |
| | Goals | Configure game | Learn UI | Learn UI | Solve puzzle; Maximize performance | Maximize performance | Maximize performance |
| Learning | Actions | | | Observe | Repetition; Imitating; Experimenting | Verifying/ reviewing | |
| | Tools | | | Tips | Challenge | Report | |
| | Goals | | | Remembering | Remembering | Understanding | |
| Intrinsic Instruction | Actions | | | Demonstrating | Scaffolding; Repetition; Recover from errors | Quantitatively assessing performance; Rewarding good performance | |
| | Tools | | | Tips | Challenge; Multiple Chances; Limited set of choices | Performance measures | |
| | Goals | | | Providing learning guidance | Eliciting performance, confidence | Providing feedback; Assessing performance | |

Figure 2.12 Activity Theory Based Model [Carvalho et. al]

**Serious Gameplay Framework**

In his thesis, Hall [2015] proposes a ‘Serious Gameplay Framework’ (SGF) as a practical toolset for serious game designers. SGF intends to address the shortcomings of earlier models, especially their inability to provide practical guidance on the design of game elements. SGF is a collection of tools, processes, and design techniques for serious game analysis and design. Serious Core Gameplay Tool (SCGT) is one of the tools in the framework to help designers identify task-based competencies from the learning goals and embed them in core gameplay. The SCGT as shown in figure (2.13) guides designers in the design process through a set of questions. While the tool provides leading questions for integration, the specific design strategies that can answer these questions are not part of the framework.

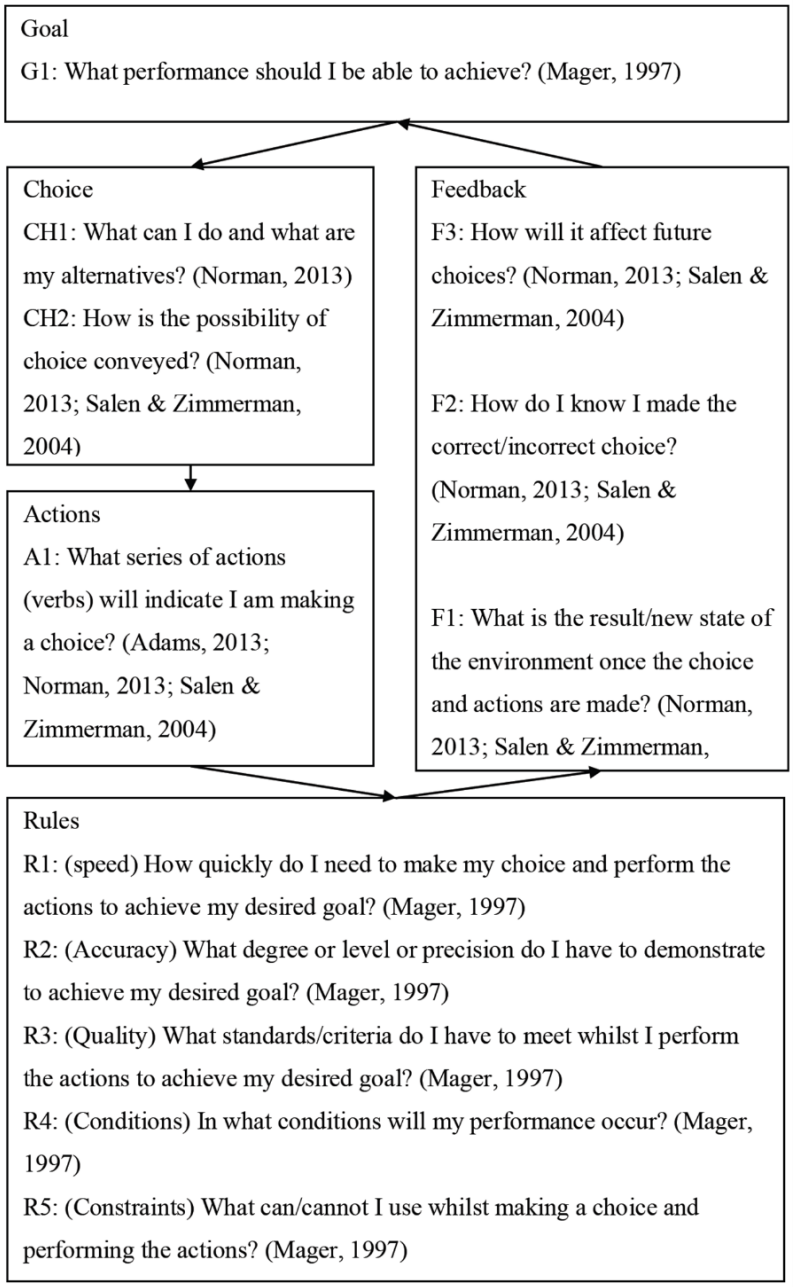



Figure 2.13 Serious Gameplay Framework [Hall]

**Method for Gameful Design**

Deterding [2015] proposes a method for 'gameful design' consisting of five design steps as reproduced in figure (2.14). Though he has proposed this model for use in the context of gamification, the key according to him is to identify the challenges inherent in the users' pursuit of their needs. These challenges can then be restructured into gameful design. This approach of extraction of inherent challenges and restructuring into game elements is of interest to endogenous design. This method focuses on identifying challenges in the context rather than the content. It informs about what to do (identify challenges) but not how to do it.

| INNOVATING | EVALUATING |
|---|---|
| **1 Strategy** | |
| a. Define target outcome and metrics | |
| b. Define target users, context, activities | |
| c. Identify constraints and requirements | |
| **2 Research** | |
| a. Translate user activities into behavior chains (optional) | |
| b. Identify user needs, motivations, hurdles | |
| c. Determine gameful design fit | |
| **3 Synthesis** | |
| a. Formulate activity, challenge, motivation triplets | a. Identify skill atoms of existing system for opportune activities |
| **4 Ideation** | |
| a. Brainstorm ideas using innovation stems | a. Brainstorm ideas using design lenses |
| b. Prioritze ideas | |
| c. Storyboard concepts | |
| d. Evaluate and refine concept using design lenses (optional) | |
| **5 Iterative Prototyping** | |
| a. Build prototype | |
| b. Playtest | |
| c. Analyze playtest results | |
| d. Ideate promising design changes | |
| *Repeat steps a-d until desired outcome is achieved* | |
| *Increase prototype fidelity as playtest results approach desired outcome* | |

Figure 2.14 Method for Gameful Design [Deterding]

### 2.4.3 Summary of Integration Literature

There is a consensus among researchers that merely coating learning content with a layer of game will not lead to effective games. While several authors have worked on learning-playing integration, the focus has been largely on mapping instructional objectives to game elements. Few process models indeed indicate atleast a step to integrate content into gameplay, but do not specify any techniques and tactics to do so. How deep or superficial the implementation of these steps should be is left to the designer's discretion and ability. In summary, the existing work on models for integration of content into the game elements is limited, and lacks specific strategies necessary for endogenous design.

## 2.5 Endogenous Design

### 2.5.1 Need for Endogenous Design

Content and gameplay can be integrated in several ways but only some will yield desirable outcomes. Deen [2015] enlists ways in which the integration of learning and games can become ineffective. He refers to these approaches as pitfalls in educational game design. They are:

a) Inserting content in unrelated gameplay: In this approach, the learning content is inserted in an unrelated gameplay. An example of this is a game with a purpose to educate players about animal cruelty. The game uses a platformer design such as Mario as a base. The educational message in the form of cruelty is inserted as various signposts. This is poor integration because the game is about timing jumps and not related to the intended message.
b) Inserting game elements in content: In this approach, unrelated gameplay is inserted in learning content. An example would be mini fun games that would appear as a reward after successfully finishing the reading of a topic.
c) Embellishing content with fantasy visuals: Some games merely embellish learning exercises with fantasy themed visuals (e.g. the Chocolate Broccoli Approach). Again, the content and gameplay are not related. Typically, eLearning tools follow this approach. There is no real game but just game-like appearance and characters.
d) Hybrid approach: In a hybrid approach, the games and learning exercises are two separate entities appearing alternately, unrelated to each other. The player is made to learn, then play, and then learn again. Deen gives the example of a math game where players must solve arithmetic calculations to acquire powers for shooting alien warships.

Designs created using each of these approaches are likely to create frustration in playing as well as learning. Knowing that such prevalent approaches will fail the educational games, the need for coherence through intrinsic integration or endogenous design is starkly felt.

### 2.5.2 Intrinsic Integration

Malone [1980] uses the ‘motivation’ lens to distinguish between two kinds of integration, one based on extrinsic motivation and other on intrinsic. Extrinsic rewards can work in the short term but run the risk of destroying any intrinsic motivation a learner may have toward achieving learning goals. The integration approaches discussed as pitfalls earlier, fall in the category of extrinsic integration. Therefore, Malone proposes designing intrinsically motivating learning environments. According to him, incorporating challenge, curiosity, fantasy, control/choice, cooperation, and competition in the design is essential to build motivating environment.

Malone and Lepper [1987] further introduced the terms endogenous and exogenous fantasy. These terms indicate the mode of integration of educational content in the games' fantasy world. In endogenous fantasy, the skill and fantasy depend on each other but not so in exogenous fantasy. Banking on the potency of intrinsic motivation, Malone hypothesizes that 'endogenous fantasy', in which content is intrinsically related to fantasy, produces better learning.

Squire [2006] compares endogenous and exogenous designs in educational games. The comparison is reproduced in figure (2.15). The key difference between the two is the way the learner receives the content. In exogenous games, learners are passively receiving instructions and facts, whereas in endogenous games, they are actively participating and making meaning. This is also the difference between behaviorism and constructivism paradigms. Endogenous designs support constructivist learning better. The second difference is the manner in which content is integrated with the game context. In exogenous games, the game context is a motivational wrapper to the content whereas in endogenous games the content itself forms the game context.

| Aspects | Exogenous Games[a] | Endogenous Games[b] |
|---|---|---|
| Learner is . . . | An empty receptacle. An example is *Math Blaster,* where the learner is "motivated" to learn a prescribed set of skills and facts. | An active, sense-making, social organism. An example is *Grand Theft Auto,* where the learner brings existing identities and experiences that color interpretations of the game experience. |
| Knowledge is . . . | Knowledge of discrete facts. The facts are "true" by authority (generally the authority of the game designer). | Tool set used to solve problems. The right answer in *Civilization* is that which is efficacious for solving problems in the game world. |
| Learning is . . . | Memorizing. Learners reproduce a set of prescribed facts, such as mathematics tables. | Doing, experimenting, discovering for the purposes of action in the world. Players learn in role-playing games for the purposes of acting within an identity. |
| Instruction is . . . | Transmission. The goal of a drill and practice game is to transmit information effectively and to "train" a set of desired responses. | Making meaning/construction, discovery, social negotiation process. Instruction in *Supercharged!* involves creating a set of well-designed experiences that elicit identities and encourage learners to confront existing beliefs, perform skills in context, and reflect on their understandings. |
| Context is . . . | A motivational wrapper. The context in *Math Blaster* is something to make learning more palatable. | The "content" of the experience. In *Civilization,* the geographical-materialist game model is the argument that situates activity and drives learning. |

Figure 2.15 Contrasting Endogenous and Exogenous Games [Squire]

### 2.5.3 Defining Endogenous Design

An integral, continuing relationship between the fantasy context and the instructional content is defined as intrinsic fantasy [Malone, 1980]. The exclusive focus on integration with the 'fantasy element' of the game is limiting. Learning happens through various parts of the game, and all of them should be the potential candidates for integration [Habgood et al., 2005].

In designing a learning game, the temptation to graft academic content onto existing game forms should be avoided [Klopfer et. al, 2009]. Such exogenous design may render games that are neither fun nor educational. According to Klopfer et. al [2009], a desirable approach is to connect players with fundamentally engaging elements of the subject. In this approach, the player is not tricked into engaging with the topic by external means, but the chosen elements of the content are made exciting so that the player is motivated to explore deeper. This is a fine description of endogenous design approach.

The term 'endogenous' literally means having an internal cause or origin i.e., generating from within. This term is borrowed from biology, where endogenous indicates elements growing within the organism such as tissues or cells in a body. Exogenous on the other hand is the element inside the organism but originated outside, such as a pathogen. The idea of endogenous design is to identify fundamentally game-like elements in the content and translate them into game elements. Klopfer et al. [2009] indicate that these elements often already exist in academic subjects, if not always. These elements are, to quote the authors, "the questions that practitioners enjoy mulling over, or playing with in their spare time, the kinds of musings that lead to 'aha moments'". Deen [2005] refers to these elements as 'restructurable' elements – those that readily stand out for translation to a game.

Using the basis of this literature, a definition and the principles of endogenous design are crafted further. The term 'design' is used as a noun and not as verb in this definition.

**Definition**

*A design, in which game elements are derived by restructuring the elements of the educational content, is termed as endogenous design.*

The principles of endogenous design are as follows:

1. Endogenous design implies integration of content elements rather than instructional strategies with game elements.
2. The integration between content and gameplay is seamless. Quoting Rieber [1996], "One cannot tell where the game stops and the content begins".
3. Due to seamless integration, the act of playing and learning becomes inseparable. If learners are interested in the play, they will consequently be interested in the content.
4. Not everything offered in the traditional curriculum may lend itself to this approach [Klopfer, 2009] because some topics/content may not offer restructurable elements.
5. Endogenous design is a continuum rather than a binary. It is unlikely that the game is entirely endogenous or exogenous, but designs can lie somewhere in between.

### 2.5.4 A Case for Endogenous Design

The primary reason for proposing the endogenous design of games is the promise to fulfil the function of education and fun simultaneously. However, there are other pros and cons while making a case for endogenous design, which are discussed further.

**Effectiveness**

Habgood and Ainsworth [2011] hypothesize that intrinsically integrated games (endogenous designs) are more effective than extrinsically integrated games. Two points support their argument, a) the gameplay creates a deeper connection with the learning content and b) the inherent learning creates a superior level of motivation within the game. Habgood et al. [2011] designed games with different types of integrations and conducted several studies to test the hypothesis. Their studies offer evidence that the intrinsic approach leads to effective educational games. Gunter et al. [2008] concur that relative tightness of the coupling and embeddedness of content in the fantasy world are a valid, reliable predictor of engagement. Though more studies with varied content types and contexts can strengthen the claims, there is a wider agreement currently, that endogenous design will make educational games effective.

**Applicability**

Endogenous design may not be the panacea for all ailments of educational games. As indicated by Klopfer [2009], not all kinds of educational content may be amenable for translation to endogenous games. Endogenous designs can be created for different content types such as factual, procedural and conceptual. However, a specific subject may not have elements that can be easily extracted and translated to games. In such cases, exogenous designs may be created.

Further, from a designer standpoint, endogenous design will apply predominantly to a constructivist/instructionist approach, where the content is delivered to the learners by integrating with a game. In a constructionist paradigm, the content is not 'delivered' but learners construct their own knowledge in a sandbox-like environment. Kafai [2006] points out that constructionist approaches in games generally imply learners building their own games by exploring the topic. While students can still use our framework to construct their own games, our focus is on enabling designers to embed content in games through endogenous design.

**Design Effort and Expertise**

Habgood et al. [2011] argue that designing exogenous games is cost-effective because the modules of learning and gameplay are separate, so these modules can be easily repurposed or combined. In contrast, games with endogenous design cannot reuse the gameplay across different content. This is because gameplay will be designed specific to the content. Reiber [1996] also indicates that determining an appropriate endogenous fantasy for every topic is difficult. Not only does endogenous design require more effort, time and cost, it requires expertise in observing and extracting restructurable elements from content and translating them to novel gameplay. Further, there is no readily available guidance on achieving endogenous design. Therefore, endogenous designs will require more effort to design.

**Are Exogenous Designs all Bad?**

While making a case about the virtues of endogenous design, it may seem that exogenous designs are always unhelpful. That may not be true. Habgood et al. [2011] has found that even without endogenous design, games can act as motivational anchors. The game can be peripheral to the content, but it can still enhance motivation for learning. If exogenous designs are able to encourage learning, it can be argued that endogenous designs are likely to perform even better.

### 2.5.5 Parallels in Other Domains

We have sought to know if the concept of endogenous design is relevant in other disciplines of design, but we found very little evidence. A unique approach, however, is found in games for promoting social causes through games [Kauffman and Flanagan, 2015]. The approach focuses on two design strategies that covertly deliver persuasive content to overcome the player's psychological barriers and create a more receptive mindset, instead of a direct in-the-face approach. The first strategy of intermixing related and unrelated content to make the focal message less obvious is partly endogenous. The second strategy of obfuscating - to divert the player's attention while delivering the message is exogenous.

A concept similar to endogenous design is indigenous design. In indigenous design, the design elements are drawn from within the culture or locale. In architecture and product and interaction design, this term is used to indicate situated-ness in a specific context. The strategies for indigenous design include understanding the locale, deriving solutions from the problem space, and including design elements that merge the solutions with the context. Strategies for endogenous game design can draw from these parallels.

## 2.6 Insufficient Guidance

Before we discuss lack of guidance, we briefly describe what would constitute design guidance. According to Delft Design guide [Van Boeijen et. al 2014], designing is an activity that is supposed to lead to new possibilities and an embodiment of those possibilities. While dealing with uncertainty and possibilities, designers could ask a number of questions: Where do I begin? Which steps do I take? Which phases will I go through? Is there a reference method that I can use? When can I stop analyzing and start creating? and so on. A design guide is a reference that includes methods, processes, steps, strategies, tactics, and tools that the designers can use during and after design education to address such questions. Beyond their practical utility, design frameworks provide a common language for designers and researchers to discuss, transfer and advance design knowledge.

The current literature is unanimous in recommending endogenous design as a promising approach to designing educational games, but there are very few attempts at discovering and proposing methods/strategies/ways to achieve endogenous design. Ibister et al. [2010] conducted a study spanning a couple of years to capture the insights of successful game designers. Designers reported their preference for embedding content material deep in the game mechanic and goals, instead of ‘bolting it on’. This indicates that designers have awareness as well as some tacit knowledge about attempting endogenous design. This knowledge is, however, not explicated nor available as a reference for designers.

There have been a few attempts towards developing an approach for endogenous design. Habgood et al. [2011] have suggested a process beginning with understanding the learning content, followed by design of game mechanics, and finally the fantasy context. Fertile learning content can be used to create layers of game mechanics that reinforce the learning goals. They emphasize that core mechanics have a role in creating an intrinsic relationship between games and the content.

Further, Deen [2015] proposed a specific approach for integration as reproduced in figure (2.16). The approach is to split the content elements into restructurable and fixed elements. Restructurable elements in the content can be translated to the gameplay and fixed elements to the game setting (refer dotted box). The step after translation is for designing elements of competence, autonomy and relatedness, which was the core focus of Deen's thesis.

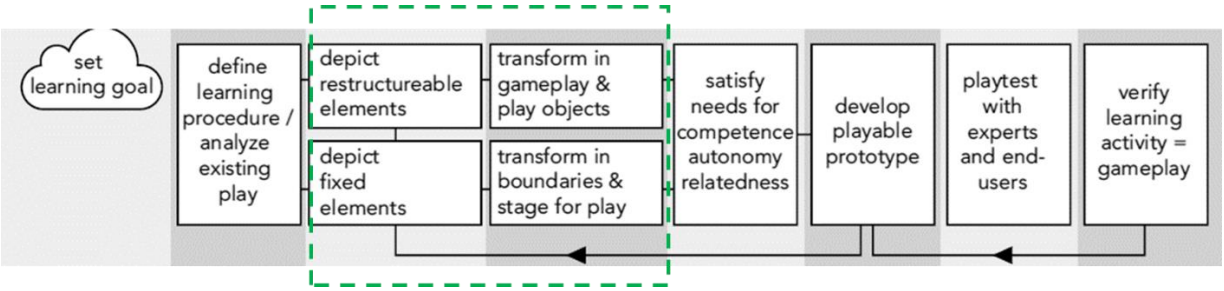



Figure 2.16 Integrated Design Approach [Deen]

A literature review by Ke [2016], with exclusive focus on intrinsic integration, offers valuable insights on the state-of-the-art. She extracts and presents five broad themes of integration through her analysis of selected literature. These themes are a) purpose either prior knowledge activation or new knowledge acquisition or both, b) transfer mechanisms such as learning through representation, simulation, or contextualization, c) blended learning spaces contrived by mapping learning actions into mechanics or the game world, d) iterative learning moments, and e) in game learning support. The theme on blended learning spaces provides few hints on the integration that lead to endogenous design, but she finds a general lack of specific design strategies for content-game integration. Her quote at the end of the review sums up the state-of-the-art: "In spite of the plethora of research on the topic, the account of what, how, where, and when domain-specific learning is integrated into gameplay remains murky".

The current approaches discussed in literature review are inadequate to aid endogenous design. None of the integration approaches provides specific methods or strategies to integrate content into gameplay other than the brief mention of restructurable elements by Deen [2015]. Mapping models focus on mapping of pedagogic elements, and process models are at a macro level and just indicate a step for integration without providing specifics. Bellotti et al. [2010], who investigated the current research on serious games, reached a similar conclusion. They report, "Despite the abundance of literature on serious games, only few papers provide specific strategies through which a topic is 'translated' into a game". Table (2.3) summarizes the current state of knowledge and the gaps found in the endogenous design space through literature survey.

Table 2.3 Gaps in Literature

| Source | Current State and Gap |
|---|---|
| Literature on learning game integration problem | • Near universal support for avoiding chocolate coated broccoli approaches |
| Literature on mapping learning-game elements | • Macro level guidance about mapping instructional objectives to game elements |
| Literature on solutions for integration - endogenous design | • Differentiates endogenous and exogenous designs<br>• Discusses pitfalls in exogenous design<br>• Few studies on effectiveness of endogenous design |
| Literature on guidance for endogenous design | • Only couple of macro approaches<br>• Lack of specific strategies and guidance |

The current state of the literature clearly presents a research opportunity for the development of guidance for the endogenous design of educational games.

## 2.7 Trying out Endogenous Design

Knowing that detailed guidance on endogenous design is not available, firsthand exploration of the approach and challenges of endogenous design was necessary. We conducted two exploratory studies to understand the nuances of endogenous design: a) designing an endogenous game firsthand and b) conducting a workshop with participants from design school.

### 2.7.1 Design of a Game - Entangle

The activity started with a design brief inviting an endogenous educational game for geometry. First, we studied the chapter on basic shapes, which was to be taught through the game. The content primarily consisted of various shapes, their names, and some properties. The students were to learn these shapes through visualization. We started exploring ways to design that game. It was decided to break away from standard digital designs where there is a character and story. Visual representation was a promising option and a board game served well for that purpose. What would the game comprise? Answering this question needed some decisions on mechanics, resources etc. An outside inspiration led us to think of ‘sticks’ as sides of the shapes. The sticks became tokens/resources that players could use to make shapes. Where would they make these shapes and what would the challenge be? A layout design that answered both these questions came up after some trial and error. The final design is explained further.

Entangle is a board game designed for middle school students to learn basic shapes in geometry. The board as illustrated in figure (2.17) has a printed array of equilateral triangles with sides meant for placing tokens (sticks). Players place a stick on the board on their turn. The placement of the stick can result in an angle or a polygon. The player then identifies the shape created and collects a corresponding card from the bank. Each card has a picture of a shape and points for that shape. The players have to maximize their points in order to win. Hence, they need to create and identify angles, triangles, parallelograms, rhombuses, trapeziums, and hexagons that are formed because of placement of a stick.

In this game, the game elements (board layout, sides of shape, how smaller shapes make up larger shapes etc.) emerge from the content. In addition, the act of learning the shapes and the act of playing are inseparable. Hence, this is an endogenous design. The game was tested in the field with school students in a formal study. It was found that the design could balance fun and learning [Athavale and Johry, 2015]. Players had fun while playing, which was confirmed based on the interest in repeat play. In addition, there was a significant difference in knowledge in the pre and post session tests.


Figure 2.17 Endogenous Design Example - Entangle Game

From the endogenous design standpoint, this exercise provided the following insights:

a) Exploring the content/subject matter using several lenses is important. It is necessary but not sufficient to understand the topic. It is required that the designers think about the content in several ways – making several connections and creative compositions of elements observed.
b) Generating a game idea from the content did not come easy. Several elements need to be tried as starting points.
c) After an anchor element was designed, the rest of the game could be built with greater ease.
d) Not all the elements need to come from the content. In this game, the rules for turn taking were dice based. This is a standard game mechanic and not specific to the geometry content.
e) Additional properties of content elements can be explored, transformed, extended, and morphed. However, a constant check is needed to know if the game idea/rules are truthful to the learning content.

### 2.7.2 Design Workshop

We conducted a game design workshop at a reputed design school in Mumbai. The objective of the workshop was similar to the Entangle design, i.e. a preliminary exploration of the endogenous design activity. However, the workshop had an additional objective, which was to understand how designers treated the various topics and whether some are too difficult or too easy to translate to endogenous design. The shortlisted topics from this workshop would then be used for the main studies.

The participants in the workshop were Master's students who had taken a course on game design. They were briefed about the concept of endogenous design, and the example of Entangle game was shared in advance. The topics from middle school representing various content types [Anderson et al., 2001] were selected. The session duration was three hours for designing two concepts and each designer was required to design individually. Assigning a topic to two or more designers jointly may not have given an accurate picture of the topic's complexity. Topics were exchanged midway. Figure (2.18) shows the workshop in progress.

Figure 2.18 Exploratory Workshop in Design School

The observations from the workshop are organized in a chart shown in figure (2.19). The assigned topic is indicated in column A and content type of that topic is in column B. Columns C to G indicate the parameters of interest for endogenous design. These parameters were discovered from the observations.

| | **A Topic and type of content** | **B Type of Content** | **C Properties derived from the content** | **D Humans in the context** | | **E Contest Candidates** | **F Selected Elements** | **G Gameplay** |
|---|---|---|---|---|---|---|---|---|
| | | | | **Goals** | **Behaviors** | | | |
| 1 | Rocks and Soil in Geography Grade 7 | Factual | Rocks can formed and broken | Use rocks and soils for various purposes (agriculture, construction etc) | Humans use rocks and soils for various purposes | Build vs break | Use of properties Structure Spatial | Players collect rocks and build their own castles and destroy opponents |
| 2 | Force in Physics Grade 9 | Conceptual | Force creates motion Force stops motion | Use force to move objects | Humans use force to do work | Contest - block opponent while pushing own tokens | Use of properties, objects, movement | Players have to use force on a grid to move tokens to other end |
| 3 | Reflection of light in Physics Grade 8 | Conceptual | Objects that reflect light e.g. Mirrors, that converge/ diverge light (lenses), darkness, shadows | See something, hide something | | Pass light rights, block light rays | Use of properties, objects, movement | Players have to use principles of ray of light and the mirrors etc to take ray to other end |
| 4 | Atoms, Molecules, Reactions in Chemistry Grade 8 | Conceptual, Factual, Procedural | Atoms can combine to form molecules, molecules can participate in reactions | Combine elements | Humans use specific compounds for specific uses | Make or break compounds | Use of structure | Players have to collect pieces from the bank to create own structure and block opponents |
| 5 | Fundamental Rights in Civics Grade 7 | Factual | Rights are permanent Rights come with responsibilities | Use rights for better living | Misuse, Infringement, lack of awareness of rights | Crime, suppression vs rights Responsibility vs Rights | Simulation - Role play Decision making | Players have to use rights to overcome situations |

Figure 2.19 Observations from Exploratory Workshop

Column C indicates the prominent properties of the content extracted by the participants and column D indicates the role of humans in the context (what people do with the elements in the content, their goals and behaviors). Further, column E indicates the contest candidates (elements that can have some tension or conflict between them), column F indicates the elements selected by participants for creating gameplay and G indicates the proposed gameplay.

The design decisions made by the participants for each parameter are indicated in cells of the table in figure (2.19). Although data was collected on 18 topics, a sample of five is presented in the table for brevity. Based on the data collected from the workshop, the following strategy themes were identified:

a) Participants looked for ‘gameable' elements from the content. This required surfing through the various elements of the content, noting the structures and properties of elements including physical properties, spatial layouts, temporal movements etc.
b) Participants looked for the role of humans in the context and aimed at identifying the goals and behaviors of people in the context. For example, if the topic is Force – the human goal can be ‘move objects', and the behavior could be ‘move owns object’ faster and ‘block opponents’. Designers also studied the interactions between people as well as interactions between people and objects.
c) Participants looked for contesting elements. This involved finding elements/properties that could be pitted against each other or behaviors that opposed each other.
d) Participants either selected a suitable gameplay based on prior experience of games or generated novel gameplay based on content.
e) The type of content had a bearing on the type of gameplay. For example, the topics environment management and fundamental rights could be translated into a game of challenging situations, whereas topic force was converted to a token ‘movement’ game.
f) Participants also introduced some amount of fantasy (though not indicated in the table) to make the game interesting. For example, in the geography game, some rocks were given magical properties such as disappearance, which do not exist in the real world.
g) Participants created an endogenous design of varying degree. For example, in the game on molecules and reactions, players have to assemble appropriate atoms with holes and bulges to fit into each other to form molecules.

The workshop helped us in confirming that study of the design activity could lead to the understanding of tacit ways to achieve endogenous design. It also helped in shortlisting topics for the main studies. The selected topics are discussed in the next chapter.

## 2.8 Degree of 'Endogenousness'

Endogenous and exogenous design may appear as two ends of the integration spectrum, but in practice, endogenous design can be of varying degrees. The endogenous nature can be evaluated by counting the number of elements that are translated from the content to gameplay. The endogenous nature of the design is not binary but a continuous scale as indicated in figure (2.20). However, it can get more complex than that when weightages are attached to the elements. For example, translating an element to game mechanics or resources creates a strong impression about the endogenous nature of the game, compared to simply translating information.

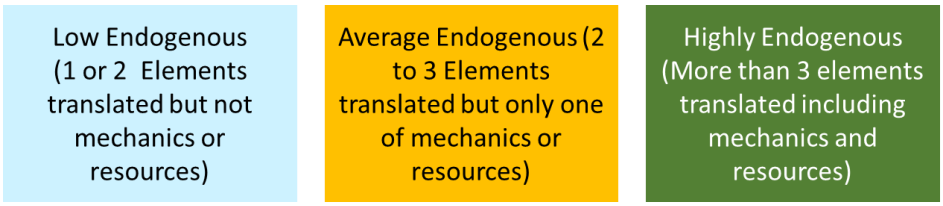



Figure 2.20 Continuum of Endogenous Design

**Evaluating Endogenousness**

Most of the 'mapping models' discussed earlier have also been proposed as tools for the evaluation of learning games. However, very few help in evaluating 'endogenousness'. Gunter et al. [2008] have created a 'RETAIN' rubric for the evaluation of educational games. This rubric has one parameter on 'embeddedness', which is a single parameter scale indicating the exogenous or endogenous nature of games. A rubric proposed by Stewart [2015] is more detailed as it works with four parameters measuring integration of content in digital educational games. Some of the parameters identified by Stewart include:

a) The strength of relationship of game content to learning goal
b) Problem-solving characteristics – how well the game provides scaffolded learning, leading toward solving problems
c) Integration of knowledge content in game – how well the content is embedded in the game and whether learning helps natural advancement in the game
d) System thinking – whether the game elicits system thinking or otherwise
e) Feedback – how well the game provides feedback and enables players to learn from mistakes

Using Stewart's instrument as a baseline and drawing insights from other literature, we have proposed a rubric for measuring endogenousness as shown in figure (2.21).

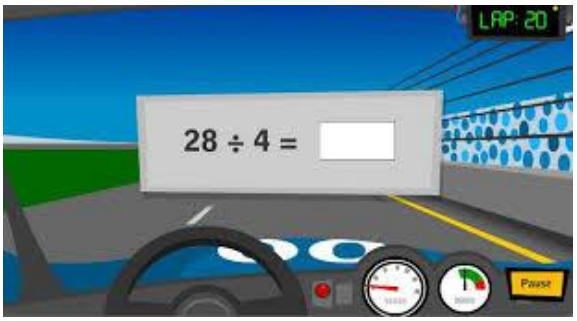
| Degree of Endogenousness --> | Exogenous | Low Endogenous | Moderate Endogenous | High Endogenous | Evaluator Rating |
|---|---|---|---|---|---|
| Rating Value --> | 0 | 1 | 2 | 3 | |
| Parameter for evaluation | | | | | |
| Embeddedness of player actions within the learning | Act of playing the game and act of learning are unrelated | Act of playing the game and act of learning the topic has some overlap (e.g. small part of game actions/ resources/ rules are related to intended learning) | Act of playing the game and act of learning the topic are has a lot of overlap (e.g. large part actions/ resources/rules are related to intended learning) | Playing the game and act of learning are not separate. There is significant overlap barring few exceptions | |
| Embeddedness of game and content elements | No embeddedness. Game like visuals around learning content | Forced embeddedness. Relevant quests in between game which require to be solved to gain points to progress in the game | Some of the game elements are derived from content - either of game mechanics/goals/setting/resources/rules | Significant game elements are derived from content - two or more of game mechanics/goals/setting/resources/rules | |
| Balance of Reality (elements of topic from real world) and Fantasy (elements related to the topic which are not real) | It looks like either a) a simulation world with no fantasy elements OR b) a fantasy world with no semblance of reality | The design is more of fantasy or more of reality with little mixing | The design balances fantasy and reality by extending some of the real world elements | The fantasy and reality are well integrated and its not easy to separate them out | |
| Integration of pedagogic elements (scaffolding, feedback) | Either the learning levels and game levels do not exist or match. Also the feedback in the game is unrelated to learning. | Game levels and learning levels exist but they are well matched. Feedback is outside gameplay. | Game levels are related to learning levels at few places and some part of feedback is part of the play | Learning is gradual and matched with the game levels and the continuous learning feedback is through gameplay | |
| Overall rating (interpreted not weighted) --> | | | | | |

Figure 2.21 Degree of Endogenousness

The significant measure in our rubric is the number of elements translated from content to gameplay. This rubric has been validated through expert evaluation. Experts provided inputs on ambiguity, difficulty of rating and missing parameters to help improve the rubrics. We also verified the level of agreement across evaluators on the ratings. Currently, the final rating is not a weighted average but interpreted. The rubrics are one of the early attempts to evaluate endogenousness and will need refinement in the future.

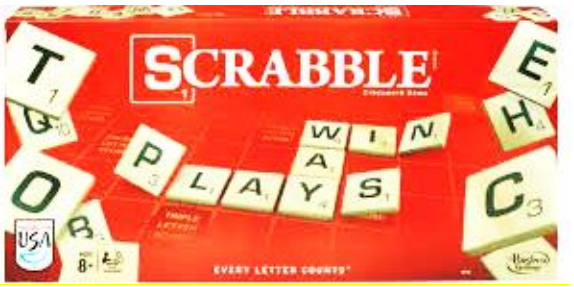
## 2.9 Endogenous Elements in Popular Games

In this section, the design of few popular games that can also be educational is discussed. We selected four games: Two (MathBlaster and Civilization) that are often referred to in literature [Squire, 2003, Deen 2015] as well as two others (Scrabble and Monopoly), which are used in a few schools for imparting specific skills [Ernest, 1986]. For each of these games (images in figure 2.22), we discuss the endogenous elements. [Image, game credits to respective owners].

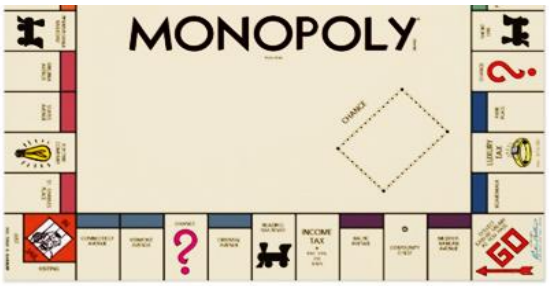



MathBlaster


Civilization




Scrabble




Monopoly

Figure 2.22 Popular Game Examples

**MathBlaster**

MathBlaster is an educational game intended to provide learning in mathematics to school students. It has various versions that support learning of basic operations of Algebra. The review of this game in several papers indicates the 'exogenous' nature of the design. The gameplay does not emerge from the learning content, nor is the learning seamlessly integrated. The gameplay involves racing or blasting asteroids in space. Math operations are inserted in between the play. The math questions need to be answered correctly to continue playing successfully. As the players solve unrelated questions during play, it makes the learning appear as an interruption rather than integration. Yet, it is worth noting that MathBlaster has done well. Probably, 'drill and practice' learning games with exogenous design add a layer of motivation beyond what just 'drill and practice' learning without games would do.

**Civilization**

Squire's analysis of Civilization [2006] indicates how learning is embedded in the game. Civilization is a game in which players creates and runs an empire while competing with other empires. Running an empire requires building cities, going to wars, signing treaties, building the economy, and so on. Squire suggests that this game is endogenous because the knowledge in this game is not acquired in the form of facts about history and geography but by living in the world to create the experience.

The design of this game is endogenous because learning is intrinsic to playing and the game elements are derived from the content. Squire suggests that "Players use these game experiences to think about why civilizations grow, flourish, fade, and how wars, revolutions, and civilizations evolve as the products of interweaving geographical, social, economic, and political forces".

**Scrabble**

Scrabble is a board game where players use letters to create words, and score points. Scrabble is used in many schools and competitions for enhancing students' vocabulary and spelling. The design of Scrabble is endogenous because part of the game mechanics emerges from the content. The selection of letters to make meaningful words is the emergent mechanic. There is also a satellite mechanic of placement in specific cells to maximize score. The letters are resources and they have weights, which are inversely proportional to the frequency of their use. These endogenous translations make the game fun to play.

**Monopoly**

Monopoly is a popular board game in which players acquire properties and wealth. Though not explicitly designed as an educational game, players learn about financial transactions and banking, apart from Maths. The design of Monopoly is a simulation of the real world with some elements of fantasy. The transactions in the game are endogenous but movement in the game is not endogenous.

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**Summary of Chapter:** In this chapter, we introduced several concepts at the intersection of learning and games. The need for endogenous design was articulated and the nuances were discussed. The gap in literature on the guidance for endogenous design was identified. We discuss the approach to develop this guidance in the next chapter.

# Chapter 3 **Discovering Strategies for Endogenous Design**

Cross [2001] suggests that design knowledge resides in people, processes, and products. We aim to develop knowledge of the endogenous design process, including strategies and tactics. This aim can be achieved through the selection of appropriate research methods, data collection, and analysis. In this chapter, we define our research objectives, scope, and rationale for selection of specific methods, research design, and the specific plan. In addition, the data collection studies, analysis of the data, and the strategies that emerge from the analysis are presented.

## 3.1 Research Objectives and Scope

The purpose of design research is to understand the phenomenon of design to improve the particular aspects of design knowledge and practice [Eckert et. al, 2003]. Our research is an instance of design research and hence has a similar purpose. The primary objective of our research is to discover methods/approaches/strategies for endogenous design. Using these strategies, we intend to develop a framework that will not only advance knowledge in the field of educational game design, but also act as a practical guidance. The research objective is met by identifying specific research questions as listed further and a suitable research approach to answer these questions.

### 3.1.1 Research Questions

The specific questions we address through our research are stated here. These questions form a series of steps in our research.

1. Current State: What is the current state of knowledge on endogenous design? What are the gaps and needs? This question is addressed through literature studies and discussed in earlier chapters.
2. Discovery: What are the methods/strategies to create endogenous designs? This question is addressed by conducting in-situ studies with designers and it is the focus of this chapter.
3. Developing a framework: How can we consolidate the set of discovered strategies and build a framework for endogenous design? This question is addressed through logical organization of emergent strategies, and it is discussed in the next chapter.
4. Validation: How useful is the proposed framework to designers in creating endogenous games? This question is addressed through the validation of the framework in field studies.

### 3.1.2 Scope

The scope of research was defined such that the objectives were attainable within the timelines of PhD course and yet sufficient to make valuable contributions to the field. The scope of the research on various dimensions is discussed further:

**Audience and Design Topics:** The canvas of educational games being vast, the scope of our research was restricted to topics from middle school (sixth grade to ninth grade) textbooks. The middle school segment was chosen for the following reasons:

a) The participants do not need expert help to understand these topics.
b) The selected age group is accustomed to playing games and is likely to benefit from them.
c) The curriculum is similar across the states in India.

It is posited that it would be possible to generalize and extend the results beyond this segment, as a part of future research.

**Medium of Games:** There is no restriction on the medium of the game. A study participant could design a game in any medium: digital, table-top, physical, or hybrid.

**Type of Content**: The educational topics are selected to represent varied types of content identified by referring to the matrix by Anderson et. al [2001].

**Design Stages**: The game design process has several design stages as discussed in the earlier chapter. The difference in design strategies for an endogenous versus a non-endogenous game would be most prominent during the conceptualization phase. Therefore, the scope of this thesis is restricted to the conceptualization stage.

**Effectiveness of Endogenous Design**: It is not in the scope of our research to prove or disprove that endogenous designs are more effective than exogenous designs. The current literature has sufficient support to claim endogenous design would be effective.

**Repurposing Games**: Our focus is on the development of fresh concepts rather than repurposing existing games into educational games. However, it is possible that the strategies may apply to repurposing but that is not proposed or validated in our thesis.

## 3.2 Design Strategies

A process to create endogenous design must consist of stages and steps. At each step, a design activity or activities are conducted using some design methods/tactics to move the process forward toward its goal [Hubka, 1983]. These individual design tactics and their combinations (strategies) form the fundamental tools of design. Our focus is to identify these fundamental blocks i.e. the design methods/steps/tactics/strategies that lead to endogenous design. In this thesis, these fundamental blocks are referred to as design strategies. *We formally define design strategies as the specific methods, working principles, and design steps in the design process that are used by the designer, toward achieving the design goals*. Design strategy in our case does not imply an overall plan or an overarching strategy to transform an initial brief into a final design, as defined by some authors [Jones 1992, Gericke and Blessing 2011].

## 3.3 Acquiring Design Knowledge

According to Cross [2001], design knowledge can be generated in three ways: the study of design artefacts (phenomenology), design practices (praxeology), and designer's knowledge (epistemology). In the field of game design, epistemology is concerned with the nature of knowledge possessed and employed by designers. Praxeology is concerned with the game design practices, methods and processes; and phenomenology is concerned with the study of games [Lankoski and Holopainen, 2017]. Though it may be possible to discover game design strategies through the study of artefacts, it will need reverse engineering to know which strategies might have led to the final designs. Currently the game design literature is biased toward studying the 'object' of the design (i.e., games) compared to the 'activity' of design.

Alternatively, studying the act of designing offers unique advantages, beyond what can be understood by playing and studying existing games alone [Mateas, 2005]. Study of design activity allows the researcher to understand how designers apply tacit knowledge while taking design decisions. Kuittinen et al. [2009] also note that the study of design activity is necessary to generate new insights. Our approach of generating knowledge is through design praxeology. Since retrospective accounts have recall bias, knowledge of design strategies is best acquired through the study of design practice, in-situ.

Gero and Kannengiesser [2004] observed, "The design research has largely adopted the scientific paradigm in which it is assumed that there are regularities that underlie a phenomenon. It is the role of research to discover and represent those regularities". Our research conforms to this paradigm as we intend to study the underlying phenomena in design practice while creating endogenous designs, to identify regularities (strategies).

Design knowledge is often meta-knowledge; it may incline less toward 'answers' and more toward 'methods leading to answers' [Hoadley et al., 2009]. In our case, the knowledge created is in the form of strategies and methods. Methods aim to guide designers in addressing recurrent design problems, enhancing the quality of design outcomes and the efficiency of design processes [Kannengieser, 2009].

Design research can also be classified using the lenses provided by Zimmerman et. al [2007]. They propose three types of design research: research on (or about) design, research for design, and research through design. The goal in 'research for design' is to develop theories and knowledge that can be applied in the practical design work. The goal of our research being development of a framework for practical use, it falls in this category of 'research for design'.

## 3.4 Research Approach

Based on the theoretical underpinnings discussed in preceding section, our research approach is centered on the study of design activity. Participants carry out this activity using their tacit knowledge. The design activity is recorded and analyzed. It is expected that the expression of designer's tacit knowledge in the form of ideas, decisions, and actions during the activity will lead to discovery/identification of design strategies. A design brief initiates this activity. The brief advises the designer to design a game for a given educational topic and to strive for endogenous design. Figure (3.1) summarizes our approach.

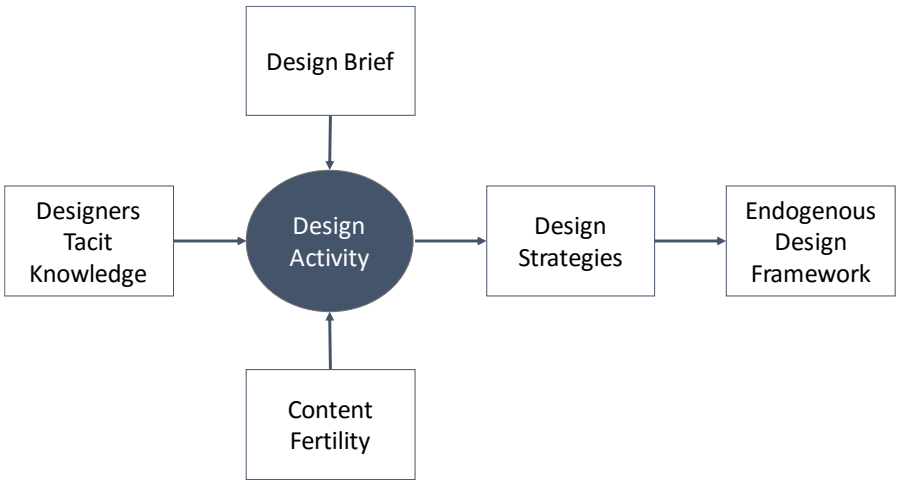


Figure 3.1 Research Approach

The core of our approach is the study of design activity, which comprises several actions that designers perform. The design activity is expected to comprise actions such as understanding the problem space, ideation-divergence, finding alternative solutions, transformations, eliminating alternatives, making decisions, convergence etc. The actions are partly similar to Gero's micro-strategies [1998]. Micro-strategies are typical actions that designers perform in a design activity. Gero's list consists of three categories: proposing solutions, analyzing solutions and explicit strategies (which relate to working with the domains). However, not all actions in a game design activity may fall neatly into Gero's list, as there is a difference between product design and game design [Tschang et al., 2006]. This means new activities and strategies can be anticipated during game design, especially so for endogenous design.

The design activity is triggered by the design brief. The brief includes the goal, which is to create an educational game with endogenous design. It also includes the educational topic, learning objective, references, intended audience and the context. Designers are expected to use the tacit knowledge to create an endogenous design. Since tacit knowledge is subjective and personal, designers perform actions and take decisions based on their prior experiences, influences, and abilities. Designers may not be aware of a specific process for endogenous design, and even if they did, they may they know the wider spectrum of strategies. Therefore, they are likely to adopt strategies that are heuristic in nature [Lawson 2006, Yilmaz and Seifert 2011].

As the heuristic approaches would differ for each designer, it is necessary to study activities performed by designers with varied backgrounds and experiences. According to Ozkan et al. [2013], there is a significant relation between participants' expertise and their design approach.

Novices can be original and different in their approach, whereas experts are likely to establish structural similarity or compliance, unless specifically asked to be innovative.

Due to the focus on endogenous design, designers are expected to draw significantly from the educational content. The studies would discover different strategies that designers use to extract the elements of interest. However, every topic and its content would have varied levels of fertility to offer 'restructurable elements' for such translations. The degree of endogenous design is likely to be a function of both content fertility and the designer's ability.

Tacit design knowledge can be made explicit through design research [Cross, 2001]. To capture and explicate this tacit knowledge, the choice of appropriate research methods is necessary. 'Think Aloud' Protocol analysis lends itself as a useful and proven method for this purpose. The research methods are discussed in subsequent sections. The design strategies would be part of this explicated knowledge and are marked/identified through coding techniques. In order to communicate the explicated knowledge in an unambiguous and usable form, it needs to be composed into a formal structure. The design strategies observed from the design activity of several designers are later logically organized into a 'framework' for endogenous design.

## 3.5 Methods for Discovery

Research methodology is the overarching philosophy or guideline for conducting research. Specific research methods enable meeting specific purposes within this broader guideline. We selected Design Based Research (DBR) as an overall methodological approach and Protocol analysis as a specific research method for data collection. The rationale for these choices is discussed further.

### 3.5.1 Design Based Research

Design Based Research is a pragmatic philosophical approach, in which the significance of a theory lies in its ability to produce practical applications [Barab and Squire, 2004]. Though DBR is predominantly employed for the study of instructional design or the design of educational technology, applying it to the study of educational games would be a natural extension. The characteristics of DBR and its suitability to our research are discussed in table (3.1). Our research aligns to the characteristics of DBR, especially the focus on practical solutions, in the form of design principles informed by existing tacit knowledge.

Table 3.1 Design Based Research (DBR) Suitability

| | **DBR Principle** | **Suitability for Our Research** |
|---|---|---|
| 1 | The research does not begin with a hypothesis but focuses on the development of solutions to practical problems, especially in learning environments through the identification of reusable design principles. | Our research also does not start with a hypothesis and intends to develop strategies for practical use in learning environments. |
| 2 | DBR is suitable when the existing practices are inadequate [Edelson, 2002] and the goal is to find new practices. | The literature survey has indicated the inadequacy of strategies/practices for endogenous design. |
| 3 | The knowledge claim of design-based research is in the form of design principles [Linn, 2004; Van den Akker, 1999]. | The knowledge claims of our research will also be in the form of design strategies (akin to principles). |
| 4 | The DBR expects development of solutions informed by existing design principles even if partial or tacit [Herrington et. al, 2007]. | We aim to identify strategies by explicating the tacit knowledge of the designers. |
| 5 | DBR suggests treating the participant as a creator rather than a subject. | Participants in our research are creators of the design. Their actions and thoughts are studied. |

However, some aspects of DBR are only partially aligned to our approach, as follows:

a) DBR is recommended for conducting research in naturalistic settings whereas in our case, participants performed designing in a lab setting. A lab setting is somewhat different from a natural setting as the designer is observed in the lab. Also in the natural setting, designers may work jointly toward a design; however, in the lab setting, we planned one participant per session. The decision of working with a single participant was to maximize the outcomes with available participants and the rationale for it is discussed in subsequent sections.

b) DBR expects iterations of the study-implementation cycle for improvements in the outcomes. In the limited scope of PhD studies, it is not practical to perform iterations of an entire set of outcomes. We did few iterations in the form of pilot studies before the main studies and validation studies after the main studies.

One of the limitations of using DBR is the lack of generalizability of outcomes due to data collection and validation in specific contexts. The data collection and validation in this thesis is also limited to a specific locale. Although, the strategies that we discovered are universally applicable, the discovered strategies may not be a universal set. More studies may be required in the future to discover additional strategies.

Several authors have proposed slightly differing steps in the DBR process. Our research follows a process closer to that suggested by Bannan-Ritland [2003]. Essential steps in their process are literature survey, needs analysis, solution design, validation, and iteration. The step that is not clearly articulated by the authors is how to arrive at the solution design. We use the protocol analysis method for explicating the tacit knowledge of designers to arrive at design strategies.

Finally, the DBR approach recommends the use of both qualitative and quantitative techniques, as appropriate. Discovering the complexity involved with human cognition, such as in design practice, demands rich qualitative data about individuals rather than quantitative data about populations [Kuipers and Kassirer, 1984]. This research, therefore, is based on qualitative methods.

### 3.5.2 Protocol Analysis

We have chosen Protocol Analysis as a method to study design activity. Protocol Analysis, is a rigorous method for eliciting verbal reports of 'thought sequences' and is widely considered a valid source for acquiring data on the thinking process [Ericsson and Simon, 1980]. In Protocol Analysis, designers are requested to think aloud while they perform design activities and take design decisions. Their tacit knowledge is thus explicated verbally.

While other methods such as Ethnographic studies, Contextual Inquiry, Logbooks, Action Research, In-depth Interviews, etc. are available for conducting qualitative studies with participants, each of these has advantages and disadvantages. Interviews give retrospective accounts but may miss vital sequences; contextual inquiry can be concurrent but may interfere with the designer's thinking process. Ethnographic studies are better suited for studying behaviors than cognitive processes, and logbooks can be cumbersome for designers.

Protocol Analysis can be done through concurrent reports and retrospective accounts. Kuusela and Pallab [2000] compare the two options and suggest that concurrent reports are better than retrospective accounts in terms of capturing content with higher fidelity. However, concurrent reports may suffer due to a mismatch between the speed of thought and that of verbalization. There is a likelihood of missing some steps in verbalization. Concurrent think aloud may also cause disturbance, and slowdown in the participants thought process. We therefore selected a median approach of using concurrent think aloud protocol followed by post-session interviews, which minimized disadvantages of both techniques. Protocol analysis therefore seems suitable for our purpose of conducting an in-depth study of the cognitive processes.

Protocol Analysis is used in a way similar to Grounded Theory [Corbin and Strauss, 1990] and does not need prior hypothesis. The theory/explanation emerges from the coding of the content. It is also considered a self-validating method due to the natural process of induction. This occurs due to the constant comparison of data between multiple participants [Rennie et al., 1988].

Furthermore, Protocol Analysis has been extensively used in design research to understand cognitive processes of designers. Motte et. al, [2004] used it to study the design strategies and tactics employed by participants during an engineering design process. Suwa et. al, [1998] used it for microscopic analyses of how particular actions contribute to the formation of design ideas. Akin and Lin [1995] used this method to explore the relationships between design activities and design decisions. Although the application of Protocol Analysis has not been observed in the study of game design, its application in other design disciplines is a sufficient basis for its suitability.

**Data Analysis Techniques**

Data collected from protocol study is coded for further analysis. The codes are assigned using an elaborate coding scheme. To make the process of coding and categorization systematic, the widely cited qualitative content analysis approach by Graneheim and Lundman [2004] is used as a baseline. It begins with the identification of a 'unit of analyses' or the 'context unit'. This is followed by coding that helps condense the data for analysis.

Codes can be predetermined based on the existing domain knowledge (deductive coding) or identified during walkthrough (inductive coding). A hybrid approach, also known as the Directed Content Analysis, combines inductive and deductive coding. We used the inductive coding technique, since it is better suited for theory development, as compared to deductive coding, which is appropriate for confirmatory studies [Kondracki et al., 2002]. The codes are expected to represent the phenomena of interest. Therefore, we coded for tactics, methods, and techniques observed in the collected data.

Coding can be performed using a process-oriented approach or content-oriented approach [Dorst et al., 1995]. The process-oriented approach focuses on design processes in terms of problem solving, i.e. problem-states, strategies etc., whereas the content-oriented approach aims at knowing what designers observe, identify, think of and retrieve from memory, while designing. Since our objective was to discover both, we looked for codes using both lenses.

Practically, recordings are first transcripted into text. After the transcription, the textual ‘quotes’ are marked against various sections of recordings. The quotes are tabulated across participants as shown in table (3.2). Then codes are then assigned to the quotes across the participants.

Table 3.2 Tabulating Codes

| | **Participant 1** | **Participant 2** | **Participant 3** | **Participant n** |
|---|---|---|---|---|
| **Code 1** | Quote | | Quote | Quote |
| **Code 2** | | Quote | Quote | |
| **Code 3** | Quote | | | Quote |
| **Code n** | Quote | Quote | | Quote |

Tabulation helps in aggregation and comparison of codes across participants. Aggregation aids in the creation of a complete set of codes. The comparison of codes between participants helps in identifying missing data, as well as highlighting the differences in the approach of each designer. The next step after this raw tabulation is the categorization of codes into meaningful groups. To avoid confirmation bias of researcher and improve reliability, independent coding is carried out. According to Krippendorff [2004], researchers can check the reliability of codes by duplicating their research efforts using independent coder and check the similarities and differences in readings. Coding of our data is presented in section {3.9}

## 3.6 Planning and Preparation

As a part of the protocol study, a participating designer performs a live design activity during one or more sessions. These design sessions are recorded and analysed post facto. In order to conduct sessions scientifically and collect required data, systematic planning is required. The planning for the studies, the research design and related decisions in our research are discussed here. The planning activity involves recruiting participants, session planning, topic selection, design-brief creation, enlisting evaluators and developing rubrics for evaluation.

### 3.6.1 Research Plan

The overall research plan is indicated in figure (3.2). The figure indicates the various steps required to conduct research. The design session is the core of data collection. This overall plan can be segmented into pre-session, in-session, and post-session activities. A session checklist is prepared as indicated in Appendix {A1}. Pre-session planning included preparation of design briefs, development of evaluation rubrics, materials setup and obtaining participants’ consent. The preparation details are discussed in section {3.6.3}.

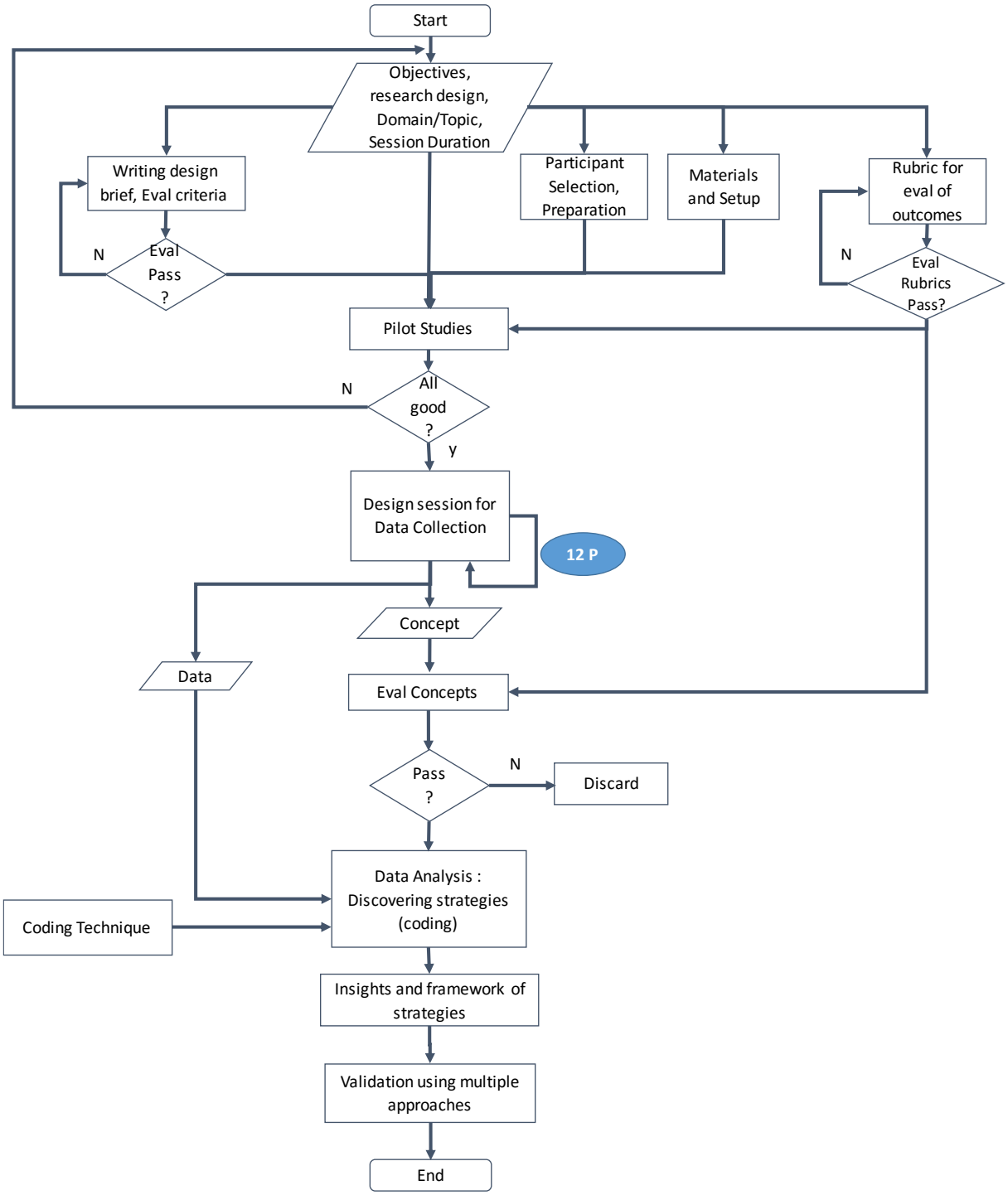


Figure 3.2 Research Plan

Before the session, the plan includes setting up a room with appropriate stationery, internet access and recording instruments. The participant will be provided with internet access for reference on educational topics. The in-session activities include a practice run of the think-aloud method to familiarize the participant. The design topic will be handed to the participant at the beginning of the design activity.

During the session, the researcher will guide the participant to break the session into four segments: understanding the topic, divergent thinking, convergent thinking, and finalizing/documenting the game concept. This breakdown is a suggestion and not expected to be strictly enforced. The concept would be documented in a template {Appendix A4} by every participant, so that there is consistency of in fields of data. The researcher should take notes wherever the reasoning of participants for their decisions is inadequate. The researcher's checklist is indicated in Appendix {A5}.

At the end of the session, the participant will do a self-evaluation. A semi-structured interview will be conducted to fill any gaps noticed by the researcher using a questionnaire indicated in Appendix {A6}. After the session, an independent panel will evaluate the concept presented by the participant. Later, the recordings will be transcripted and quotes will be attached to relevant segments of the video.

### 3.6.2 Research Design

Our research design for conducting the studies is presented in figure (3.3).

| Study Session | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 | S11 | S12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Participant | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P11 | P12 |
| Topic | T1 | T1 | T2 | T2 | T3 | T3 | T4 | T4 | T5 | T5 | T6 | T6 |
| | Civics- Fundamental Rights | | Geography - Rocks and Soil | | Physics - Heat | | Physics - Electric Current | | Chemistry - Basic Reactions | | Maths - Mensuration | |
| Type of Content | C1 (Factual) | | | | C2 (Conceptual) | | | | C3 (Procedural) | | | |

Figure 3.3 Research Design

The research design is based on one session per study, with each session scheduled for approximately three hours. In all twelve design sessions (S1 to S12) were planned as shown in Row 1 of figure, for collecting the required data. Twelve participants (P1 to P12) would participate in one design session each. Thus, P1 participates in session S1, P2 in S2 and so on, which can be inferred from Row 1 and Row 2 of figure (3.3).

Six educational topics (T1 to T6) were chosen for the game design task. These topics were selected to represent three types of content uniformly (C1 factual, C2 conceptual, and C3 procedural). The selection of topics across multiple types of content ensures that our research claims are not restricted to a certain content type. To remove any topic-specific bias, two topics for each type of content were selected. Each topic was assigned to two participants, which can be inferred from Row 3, to negate participant-specific biases. The rationale for decisions related to the duration of the session and the choice of a single participant per session are discussed next.

**Duration of Session**

Each participant was expected to perform the assigned design task in a session with a duration of three-hours. A duration shorter than this might have led to incomplete concepts, whereas longer durations would have caused fatigue. The option of breaking the sessions over multiple days/slots was deliberated but not selected. Breaking the data collection over multiple sessions would lead to loss of data. Participants are likely to think of ideas and approaches between the sessions and that would not be captured. The suitability of the duration was validated through the pilot studies.

**Number of Participants per Session**

Though a natural setting for data collection would include a team of two or more designers who jointly perform a design task, studies indicate productivity loss when brainstorming is done in groups [Diehl and Stroebe, 1987]. Researchers also have to deal with filtering out noise generated due to interpersonal behaviors and unrelated communication when dealing with group studies. Therefore, it was decided to conduct studies with a single participant in each session. This will also result in maximizing outcomes with available participants as well as having manageable data for analysis. Moreover, a single designer performing a design activity is the lowest denominator. If a strategy works for one person, it is likely to work for a group, but the inverse may not hold true.

### 3.6.3 Preparation for Studies

**Participant Selection**

Participant selection was done using a non-probabilistic purposive sampling. This approach is suited for qualitative research when the objective is to gain detailed knowledge about a specific phenomenon rather than make statistical inference. In this method, researchers make judgement about an appropriate sample. We decided to include novice, trained, and expert participants in different sessions. Designers who have spent more than a couple of years in game design were considered as expert designers. Participants who were formally trained in design schools were considered as trained, and those who had basic knowledge acquired through playing were categorised as novices. Participants were recruited through contacts in design schools and labs across multiple regions in India while ensuring variation of experience, qualification, and gender. Further, the research plan is made such that each topic is assigned to two participants with dissimilar profiles.

**Participant Preparation**

As part of the preparation, a note on the concept of endogenous design was shared with the participants in advance, along with examples of endogenous and exogenous designs. Design briefs will be shared with the participants just at the beginning of the session and not earlier. This is to ensure that no part of designers thought process was lost. During the session, the participants are expected to conceptualize a game, sketch the concept, and document it. They are not expected to develop a playable prototype. These instructions were provided to participants through a handout indicated in Appendix {A2}

**Topic Selection**

The first step for selecting educational topics for design sessions was to make a list of candidate topics. A survey was conducted with a small sample of middle-school teachers to solicit topics that were either difficult, boring or tedious to learn. Designing games for these topics would benefit the teachers and students. The reported topics were grouped into three categories: factual, conceptual and procedural. These topics were then assigned to the participants in the preliminary design workshop mentioned earlier in section {2.7.2}. At the end of the workshop, a shortlist was made by excluding topics that were too hard or too easy to translate to games. Two topics in each category were finally selected as indicated in table (3.3).

Table 3.3 Design Topics

| **Topic** | **Type of Knowledge** |
|---|---|
| **Constitution Rights (Civics Grade 7)** | **Predominantly Factual** |
| Understand the fundamental rights conferred by the constitution such as equality, freedom of speech, freedom to travel, reside and work anywhere. Also learn about children's rights, women's rights, animal rights, right against exploitation, right to education etc. | Factual, conceptual |
| Understand judicial protection of rights | Conceptual, procedural |
| Debate Rights and responsibilities | Factual, Procedural |
| **Heat (Physics Grade 7)** | **Predominantly Conceptual** |
| Understand Heat, temperature | Conceptual |
| Units of measurement and Instrument - Thermometer | Conceptual, procedural |
| Methods of transfer of heat | Conceptual |
| Expansion and contraction of substances | Conceptual, factual |
| Conductors and insulators | Conceptual, factual |
| Relate these concepts to day to day life | Factual, Procedural |

| | |
|---|---|
| **Basic Molecules and Reactions (Chemistry Grade 8)** | **Predominantly Procedural** |
| Understand Valency | Conceptual |
| Understand arrangement of the Periodic table | Conceptual, Factual |
| Know about Formation of molecules (basic molecules) | Conceptual, Procedural |
| Know about Types of reactions | Conceptual, Procedural |
| **Rocks and Soil (Geography Grade 8)** | **Predominantly Factual** |
| Know different types and properties of Rocks and Soil | Factual |
| Know formation of rocks and soil | Factual |
| Know use of various Rocks and Soil | Factual |
| **Word Problems for Mensuration (Maths Grade 7)** | **Predominantly Procedural** |
| Understanding what is given and what is asked | Conceptual |
| Organizing information, presenting visually if needed | Procedural |
| Translating to mathematics equation/steps | Conceptual, Factual |
| Solving the problem | Procedural |
| **Electric Current (Physics Grade 8)** | **Predominantly Conceptual** |
| Understanding the concept of charge and current | Conceptual |
| Knowing how current is generated | Conceptual, Procedural |
| Understanding how a magnetic field is created by current and vice a versa | Conceptual |
| Understanding the concept of Induction | Conceptual |
| Understanding how basic electrical equipment works | Conceptual, Procedural |

**Creating a Design Brief**

The design brief is a problem statement given to the participants. The design brief informs the participant about following:

a) Task: Design an educational game concept in a three-hour session.
b) Purpose of the Game: The design should meet the learning objectives for a specific audience e.g., a game to help students learn Geometry shapes where the student should be able to remember, analyze and create the shapes.
c) Topic Reference: A summary of topic contents was provided. The participants are also encouraged to refer to the state curriculum and other references. {http://cart.ebalbharati.in/BalBooks/ebook.aspx}
d) Desirable Design attributes: Desirable outcomes are endogenousness and novelty. The participants are requested to bring as many elements from the content into the gameplay as possible and avoid imitation of existing games.

e) Expected Outcomes: At the end of session, a concept note with sketches is expected from participants. A playable prototype is optional. A game-description document template is to be filled with details about various components of the game concept.
f) Coverage: The participant would have the freedom to decide the coverage of elements in the topic/chapter as long the selection is non-trivial.
g) Game Medium: The participant would have the freedom to consider any medium while developing the concept. It can be any of digital/board/card/physical.

The design briefs are created such that there is consistency in the quality and quantity of information. A sample brief is attached as Appendix {A3}

**Development of Evaluation Rubrics**

At the end of the session, designers will create a concept (and not working games). The concept will be evaluated for its 'goodness' so that the collected data from the session can qualify for analysis. It is challenging to evaluate the qualities just at the concept stage without implementing it. A formative evaluation technique, such as expert evaluation, is appropriate in such cases [Beyer, 1995]. Multiple experts are typically enrolled to perform evaluation using a pre-defined instrument. This technique has been used in the evaluation of the curriculum before it is rolled out. While there is an element of judgement in the evaluation of 'potential' impact or qualities, it can be reduced with standard measuring instrument or rubrics.

Therefore, a rubric was developed for evaluation of four measures of our interest as indicated in table (3.4). The reason to choose these measures is indicated in the table. Concepts that score poorly on any of the parameters would not be considered for analysis of data. In such cases of low ratings, it is assumed that the strategies employed by the participant are not good enough for analysis.

Table 3.4 Concept Evaluation Criteria

| Measure | Instrument | Reason |
|---|---|---|
| **'Endogenousness'** | A rubric to measure 'degree of endogenousness' was developed. It is discussed in the section {2.8}. | Endogenous design is the focus of research. |
| **Potential Engagement** | There are many instruments to measure engagement in games. The GEQ (Game Engagement Questionnaire) by Brockmeyer et al. [2004] was adopted as base instrument. At the level of concept, potential rather than actual engagement is measured. | The reason for the existence of educational games is the promise of engagement. |
| **Potential Learning Effectiveness** | Effectiveness (in educational game context) is ability of the game to cause intended learning. Keller's ARC model [1987] appears most suitable, as it has been used for evaluating instructional design e.g. Dempsey et al. [1998] used this model previously to evaluate games. Our rubrics are based on these instruments. | The educational games have to meet intended learning objectives. |
| **Novelty** | There is no easy way to measure novelty. Creative Solution Diagnosis Scale (CSDS) [Cropley et al., 2011] and other works on novelty [Sarkar and Chakrabarti, 2011] are used to develop our rubric. | Duplicates of existing concepts need to be avoided. |
| **Completeness** | Completeness is verified through the game description document. The document has sections for describing various components of the game. | The concepts should be complete in order to be evaluated. |

**Evaluation Panel**

The quality of the rubrics was evaluated by a panel of experts and corrections made before using them for the evaluation of concepts. The evaluation rubrics are presented in Appendix {A7}. The same panel of experts consisting of academicians, gamers and game designers later evaluated the completed game concepts. Two experts independently evaluated each concept.

## 3.7 Pilot Studies

The pilot studies help in testing the full execution cycle, from preparation to data collection and analysis. Two pilot studies were conducted with the aim of validating the appropriateness of the chosen research methods and for fine-tuning the research plan. Participants T1 (F38) and T2 (M26), both without formal game design experience, were selected. The choice of novices for pilot studies was deliberate. Novices were likely to bring up issues in the planning, which experts may not have noticed. The learning topics selected for the pilot studies were from the procedural content category: a) safe driving practices and b) digital banking.

T1 designed a simulation game for safe driving practices. She did a systematic study of the context, as there was no textbook content. She studied several dimensions of the space and listed the elements. Her approach to exploration was so elaborate that this systematic exploration strategy made it to the final list. She was also able to convert the extracted elements to game elements. Some elements such as resources, mechanics, and goals were easy, but she found it difficult to introduce opposition mechanic to control the movement. She had begun with a board game, but later shifted to a digital game, as it could work with automatic movement. Her final concept was a game in which two teams' race to the destination through city traffic. Players encounter traffic and need to follow or break rules to win. Figure (3.4) shows the digital sketch of her concept.

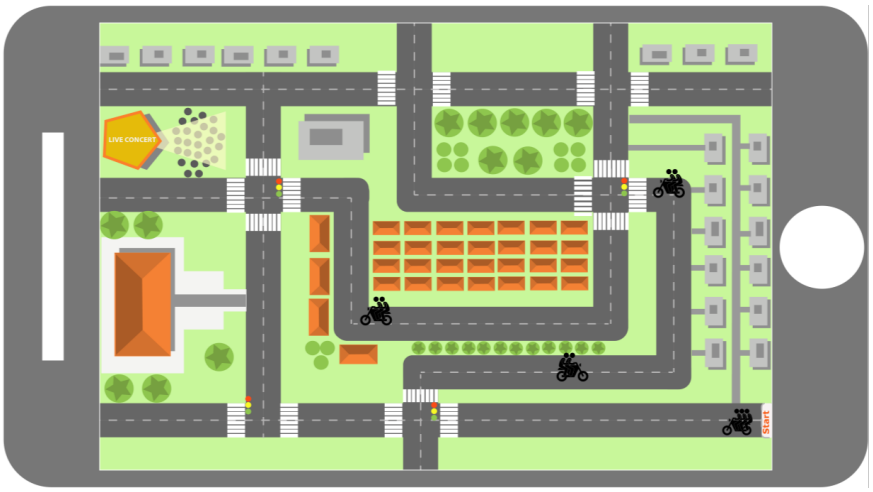


Figure 3.4 Concept in Pilot Study

T2 who worked on a digital banking game, created a fantasy world of a village market. Players in this game would play as producers and traders in this market and have to use digital transactions. The participant created a fantasy setting, with elements of the real world. The participant struggled to create a good game concept in the end. However, our objective, to understand whether the protocol worked properly, was achieved.

The data collected in the recordings was transcripted and coded. Analyzed quotes were attached to different sections of the recording and codes were assigned to these segments. In the pilot studies, our coding also covered wider aspects such as inspirations, struggles etc. and not just strategies for extraction and translation that were used. Figure (3.5) shows the experiment setup as well as the software tool, which facilitates coding. The codes were analyzed to understand the design strategies. Although each participant worked in different ways, there was some overlap and we could categorise the strategies into groups such as understanding content, translation, and creating the gameplay.

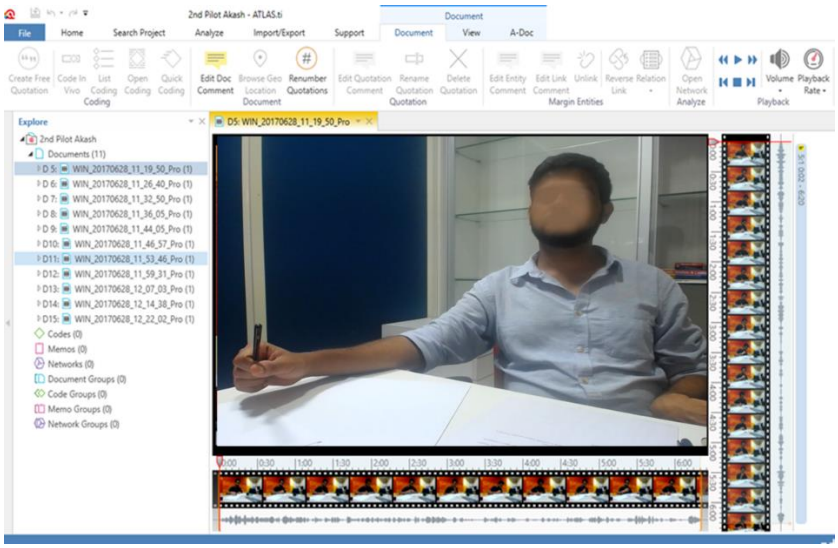

Figure 3.5 Data Collection and Analysis

The participants began with understanding the problem space. This included knowing the audience, learning objectives, and core parts of the content. The next stage was exploring and understanding the content and was key for enabling endogenous design. The participants noted various dimensions of the content, including the actors, actions, objects, environment, and constraints and so on. They also looked for unique features that they could use in the game, such as trading in digital markets that leads to digital transactions or restriction on movements due to traffic rules on road.

Following exploration, participants transformed these elements into gameplay using interesting strategies. These include, translation of the actors, actions and goals from the real world to the game world – e.g. vehicle drivers, reaching a destination and selling good etc. Fantasy was used to create a transformed context e.g. a village marketplace with different roles for players. The transformed elements were then woven into a cohesive gameplay. The participants performed trial and error with gameplay that could work with explored elements. Prior knowledge of gameplay informed this process. We observed that participants struggled with creation of movement as well as design of opposition mechanics. Game dynamics were introduced after the gameplay decisions, and included rules that led to player contests, chance etc.

As an overall approach, we observed that participants applied heuristics/self-imposed design constraints to converge on decisions and limit the scope. Participants used self-projection in game situations to gauge how the game will be received. In situations where boredom was anticipated, modifications were made to introduce fun. Table (3.5) indicates a summary of strategies discovered.

Table 3.5 Strategies found in Pilot Studies

| | Step | Strategies Used by the Participants |
|---|---|---|
| 1 | Define Problem Space | • Identify problem, players, message, core concepts |
| 2 | Explore Content | • Note down various dimensions of the content space<br>o Characters, their goals, how they behave, what they do<br>o Space, layout, constraints, paths<br>o Time, constraints, pace<br>o Objects, affordance<br>• Observe/ identify typical/ striking features |
| 3 | Transform Elements in interesting ways | • Translate (from real to game)<br>• Simulate (retain reality)<br>• Reverse (allow something that is not allowed)<br>• Fantasize (create imaginary space, powers etc.)<br>• Limit (artificial constraints of time etc.)<br>• Arrange (create paths etc.) |
| 4 | Create Gameplay | • Goals to decide purpose of movement<br>• Refer to known mechanics to create the movement |
| 5 | Create Dynamism | • Conflict between players<br>• Conflict between players goals and means<br>• Competing choices<br>• Introduce events with probability |

### 3.7.1 Learnings from Pilot Study

The pilot studies helped us in identifying gaps, ironing them out and finalizing the research plan. A summary of learnings is indicated further:

a) The session plan and preparation turned out to be satisfactory.

b) Participants requested more clarity in the design brief, which was addressed in the main studies.

c) The concurrent think-aloud protocol worked very well. Participants expressed their thought process, reasoning, and challenges during the session without any issues.

d) The decision to work with a single participant played out well and did not cause significant difficulty to the participant in ideating or closing decisions.

e) The insights from the pilot study were similar to those observed in the design workshop. This indicates a tendency of clustering of strategies in certain spaces. These findings were clubbed with findings from main studies.

f) The coding of data from pilot studies was a good preparation for coding the main studies.

After the pilot studies, the required corrections were made to the research plan. We also got a hint of strategies that would be discovered from the main studies. The important conclusions from the pilot study are published [Athavale and Dalvi, 2018]. The pilot studies thus confirmed the readiness to proceed with the main studies. The data from the pilot studies would also be considered later along with that from the main studies for analysis.

## 3.8 Main Studies

Twelve studies were planned for data collection based on our research design. We started conducting studies one by one by following the research design as shown in figure (3.3). At the end of each study session, participants created a game concept. The concept was shared with experts for evaluation. Concepts, which passed the evaluation criteria (of completeness, novelty and 'endogenousness'), were considered for further analysis. As indicated earlier, endogenousness is not binary but a continuum, so the evaluators looked for existence of atleast few elements that suggest endogenousness.

We conducted ten sessions over a period of six months. Participants with varied educational background, experience and from different geographical locations in India were recruited. The gender distribution of these ten participants was three females and seven males. Appendix {C} has details on their demographics. Nine of the initial ten concepts passed the evaluation criteria for further analysis. The recordings were analysed after every study and the analysis progressed in a cumulative fashion. At the end of nine studies, we encountered saturation of codes. As the protocol analysis method suggests a constant comparison of data across participants and the induction process can stop when the codes saturate, analysis was halted after nine studies.

This saturation might however be local maxima, attributed to the fact that the participants belonged to the same cultural backgrounds and were within the accessible circles of the researcher. More studies with participants from various international locations, cultures, and experiences may result in additional strategies (codes) that we may not have captured. The current size of data and results suffice for the claims of this thesis. Additional studies can be taken up as future research.

The summary of concepts design by the participants is listed in the table (3.6). The sketches of these game concepts are compiled in Appendix {D}, which can also serve as a library of ideas for endogenous design.

Table 3.6 Game Concepts in Main Studies

| # | Topic | Medium | Game Concept | Remarks |
|---|---|---|---|---|
| **P1** | Fundamental Rights (Civics) | Board | It is a board game with two players (as opponents). Each player has to cross the board, which has situations that demand knowledge or use of fundamental rights. | It focuses on knowledge application. Some rules are endogenous – e.g. 'Same Right can be used multiple times' (rights are not consumed after one use). |
| **P2** | Fundamental Rights | Digital | The player plays as the protagonist (a little girl), exploring her village and learning about different fundamental rights by encountering various situations and resolving them. | This was omitted after evaluation since it appeared more as eLearning. |
| **P3** | Rocks and Soils (Geography) | Digital | The player has to use a tunnel made of different types of rocks underground, and use them to create a set of objects (collectibles) above the ground. | The endogenous nature comes from the type of rocks and uses applied in the game. |
| **P4** | Not conducted | | | |
| **P5** | Heat (Physics) | Digital | It is a single-player, digital game wherein the player acts as a 'water' character whose aim is to cross a path filled with obstacles which can be overcome by using 'hot' and 'cool' points and 'powers'. | The heat and cold points are heat transfer concepts like expansion, contraction, convection and radiation. The obstacles include some temperature-based zones and a 'metal' character. |
| **P6** | Heat (Physics) | Digital | At the beginning, both the teams are randomly given an area, which could be hot summer or freezing winter. Based on the area, players in team/clan will plan their move. If their arena were cold, they would rather plan their army such a way that will sustain against the opposite player and vice versa. | This concept uses known gameplay from genre that have Clash of Clans. However, the mechanics, movement and opposition are endogenous. |

| | | | | |
|---|---|---|---|---|
| **P7** | Electricity (Physics) | Digital | The player has to help the Ants get food from the guarding Supervisor Bugs and eventually kill them to proceed to the Mother Hill to retrieve food by killing the Lady Bug who has conquered the Mother Hill. | Generator Ants will eat food, produce Energy (Electricity), and transfer that energy to the Worker Ants through a Kick or a Punch, which will be delivered to the guarding Supervisor Bugs. Thus, a metaphorical system is used to create a concept that teaches electricity indirectly. |
| **P8** | Electricity (Physics) | Real component / Board | The game requires the players to collect the pieces of a circuit and complete is as fast as they can. Once the circuit is completed, the player can see flow of charge in the circuit. Player has to block opponent from making the current ahead of the player. | The concept uses elements from the content such as resistance, cell, bulb etc. to demonstrate electric current. |
| **P9** | Basic Chemical Reactions (Chemistry) | Digital | It is a 3D world game where two players interact to build chemical-equations using available resources. The material is spherical in shape but has texture/color of the chemical itself. Players have to predict outcomes or if the outcomes are known, fill the equations with right elements. The two players can play cooperatively or can have competing goals. | The concept uses elements such as molecules, reactions to generate mechanics and resources in the game. |
| **P10** | Not conducted | | | |
| **P11** | Mensuration (Maths) | Board | It is a board game with two players (as opponents). Each player starts with a set of pre-cut shapes of varied sizes (as tokens) that can be placed on the grid to claim areas and perimeters. Each player has one colour and has to maximize scores by creating continuous patterns. Opponent has to break the pattern. | The endogenous nature appears from the calculation that is necessitated to claim larger spaces. An interesting element is use of ‘void’ shapes that can reduce the opponent’s areas. |

| | | | | |
|---|---|---|---|---|
| **P12** | Mensuration (Maths) | Digital | The player manages and runs a 'Floor Tile' making factory he inherited. The player uses informed choices, worker, material and time management to run and upgrade his factory. Apart from the game skills, player's knowledge of applied mensuration comes handy in efficiently supplying his orders. | A context is created for the content. |

The coarse observations from main studies led us to insights as below:

a) Participant's background played a role in the early ideas, for example, participants from digital game studios attempted to make character-plot-puzzle kind of games initially.
b) Participants used different ways to explore the content, and they explored at different depths as well.
c) Even after deciding/selecting several elements, participants struggled to close the concept. This was found in pilot studies too. Lack of time or lack of partner to discuss ideas could be an issue but it can also be inferred that mere combinations of elements is not enough to create games.
d) Since the participants were made aware of endogenous design, but not informed how to create it, distinctive approaches were captured.
e) The extent of endogenousness varied for every concept.
f) When engrossed in design activity, participants lost track of the extent of content and learning objectives covered. They come back to it in second iteration.

These insights would also be found in through coding and eventually form part of the emergent strategies.

## 3.9 Pre-analysis and Coding

In the pre-analysis stage, collected data was transcripted. The transcription was done manually by attaching text in the form of quotes to the respective sections of the video recording. The first pass of the transcripted text gave an idea of the overall scope and an overview of the various concepts. We could also mark the quotes with high and low significance. The identified concepts were organized into entities and their relationships. An Entity-Relationship (ER) diagram was created to visualize the concepts at a glance is indicated in figure (3.6). This diagram represents logical chunking of data for further analysis.

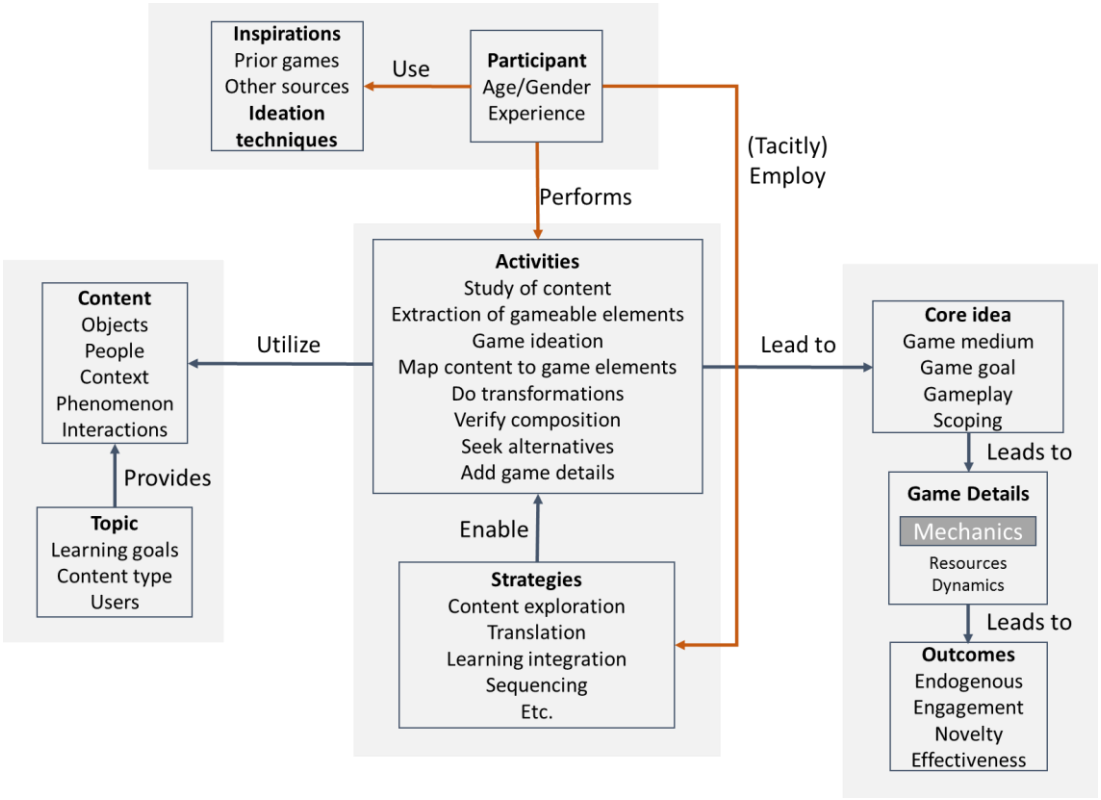


Figure 3.6 Entities in Collected Data

The arrangement has four logical groups. The first group consists of entities related to participant's demographics and prior knowledge. Participants use their abilities and inspirations to perform design activities. The second group comprises activities and strategies. These activities include ideation, study of content, transformations, evaluations, seeking alternatives, and revisions. At an abstract level, these are similar to the micro-strategies for design suggested by Gero et al. [1998]; however, their instantiation is unique in the context of game design.

The third group comprises entities related to the topic and content. This is critical area for searching elements ready for extraction. The fourth group involves entities related to game system, such as the core mechanics, opposition mechanics, and other game details. Mechanics are highlighted since they play a central role in the emergence of gameplay. The pre-analysis helped us in knowing the focus areas that relate to the research questions.

**Area of Focus**

Inductive coding does not start with a bias of expecting certain codes or phenomenon. At the same time, codes are supposed to be assigned for phenomena of interest. The phenomena of our interest are listed through the following broad questions:

a) What are the elements extracted from the content? Are there patterns? Are there some special elements in the content that are considered amenable to game design?

b) How is the core gameplay decided?

c) How are the content elements translated to the game world, goals, mechanics and resources?

d) How are the objectives of learning met? How is the design completed and verified?

e) Whether there is a pattern in the sequence followed by multiple participants?

**Identification of Codes**

Coding was done by rereading the transcripts/quotes and attaching codes to various segments of recording/transcription of each participant. In our case, we coded for strategies (tactics, methods, approaches, way of doing thing etc.) or potential strategies (actions that can be generalised into strategies). When coding was completed for the first participant and similar strategies/aspects were observed in the data of next participant, the same code was assigned. For example, P1 identified 'pervasive nature of rights' as one of the striking elements of content. P5 identified that 'physical properties of metal change when heated and cooled' as striking element. Both these cases represented the same code 'identification of striking elements'. In order to view codes across multiple participants, tabulation of codes is done using a format indicated in table (3.2). This table was shared for review of independent coders.

**Independent Coding**

As part of our research plan, two external researchers conducted independent categorization. They came up with missing as well as extraneous codes. The result of their work is shown in figure (3.7). The inputs from this exercise refined our codes and categories.

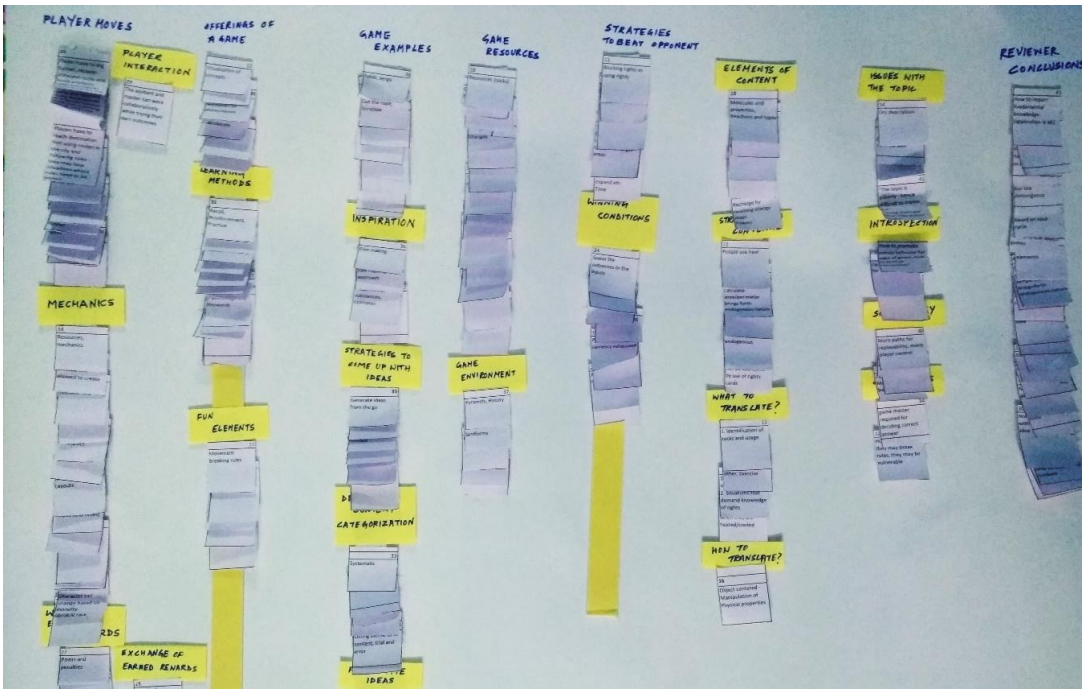


Figure 3.7 Independent Coding/Categorization

## Compilation of Codes

A section of the revised table with compilation of codes is shown in figure (3.8).

| | Main Study | 1 | 2 | 4 | n |
|---|---|---|---|---|---|
| | Participant | P1 (M 30) | P5 (F 26) | P11 (M 23) | |
| | Background | Some experience | Trained but inexperienced | Self-learned inexperienced | |
| | Design Task | Game for learning Fundamental Rights (Civics) | Game for learning Heat (Physics) | Game for learning Mensuration (Maths) | |
| | Content type (mainly) | Factual | Conceptual | Procedural | |
| <-- Codes | **Content Exploration** | | | | |
| | Striking elements | 1. The pervasive nature of rights<br>2. Situations that demand knowledge of rights | 1. The properties of substances change when they are heated/cooled | 1. Larger shapes are made of arrangement of shapes (and holes) | |
| | ... | | | | |
| | ... | | | | |
| | **Translation** | | | | |
| | Anchor element | Player Choices | Resources (materials), changes | Resources primary, and opposition mechanics | |
| | Mapping | Mechanics - obstacle race | Mechanics - obstacle race | Mechanics are "arrange" - standard for shapes | |
| | .... | | | | |
| | **Core Ideation** | | | | |
| | Prior gameplay informed | Two players have to cross the board having multiple landforms and situations (which need rights) to reach destination | | | |
| | Emergent Gameplay | | Players have to play against a system and pass through channel using heat and cold as tools | Players have to arrange the shapes on a grid to form larger shapes and claim points for area/ perimeters | |
| | ... | | | | |
| | **Game Detailing** | | | | |
| | Content Inspired | Opposition mechanics - The situations challenge the rights and block the movement which can be overcome by use of rights cards | Opposition mechanics - Different materials block the path and can be overcome by using heat and cold to shrink or expand etc. | Opposition mechanics - Opponent can place holes or their own cards to block creation of larger areas | |
| | Out of box | | | | |
| | ... | | | | |
| | **Learning Integration** | | | | |
| | Method - Visualization | | Visualization of concepts (expansion/contration, flow) | Visualizations of areas, | |
| | Method - Info application | Applicationb of knowledge of rights | | | |
| | Method - cognitive | | | Calculations | |
| | .... | | | | |
| | **Process** | | | | |
| | Initial Approach | Thinking of scenarios where rights are needed | Simulation, animation of phenomenon | Generate ideas from the go | |
| | ... | | | | |

Figure 3.8 Coding Sheet

In this figure, each column represents data of one participant. Each row header represents a code observed from one or more of the participants. The cells represent values (data) for each participant. The codes are grouped in five categories, which were named as Exploration (of content), Core ideation, Translation, Detailing, and Meta-strategies. The complete table is available in Appendix {C}. The codes were analyzed further to articulate a set of strategies.

## 3.10 Emergent Strategies

In this section, we present the description and analysis of the strategies discovered from coding. As indicated earlier, the codes themselves represent phenomenon of interest i.e., activities, tactics, methods, strategies which are all considered as strategies according to our definition. The emergent strategies are summarized across participants but separate examples are provided in a few cases.

**Content Exploration**

We observed three different strategies or approaches for content exploration that the participants employed. These are not exclusive of each other and it is possible that participants use multiple strategies. The first strategy was about systematic deconstruction of entire content. In this approach of content exploration, participants made a list of various elements in the content. During the full walkthrough, participants looked at various facets of the content, such as spaces, layouts, objects and their properties. They also checked actors and their actions, situations, and events. They studied interactions between actors as well as interactions between actors and objects. This is a comprehensive approach wherein it is unlikely for the designer to miss useful elements; however, it is effort intensive.

The second strategy includes approaches that rely on exploring content from specific perspectives. Perspectives such as ‘actions - what people can do with the elements of content’ or ‘objects’ or ‘situations - the worthwhile situations in the relevance of content’ were used. We named these as human-centered, object-centered, and situation-centered perspectives or lenses. In the human-centered perspective, participants identified the goals and behaviors of actors in a context. An example of a human-centered approach was the design created for the topic ‘Heat’. The participant identified goals of human actors as ‘heating the object’ to move faster on the assembly line, and cooling the opponents object to slow its movement. The schematic of the ‘heat’ game is shown in figure (3.9).

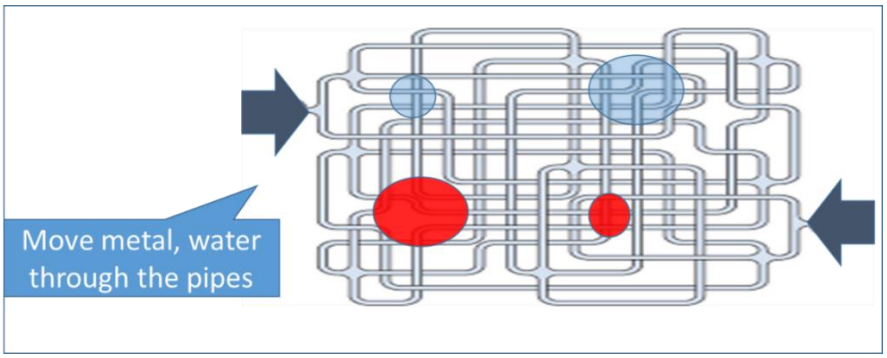


Figure 3.9 Schematic for Heat Game

An example of an object-centred perspective was observed in the topic ‘Rocks’. The objects and its properties of rocks were translated to game resources as shown in figure (3.10). In the ‘Fundamental Rights’ game, a situation-centric approach was used. The participant deliberately tried to use these perspectives to extract elements that were not easily visible otherwise. A specific perspective may also have an association with the type of content since some content has obvious elements such as objects (Physics) other have situations (social Sciences). The use of an approach other than an obvious association can bring novelty.

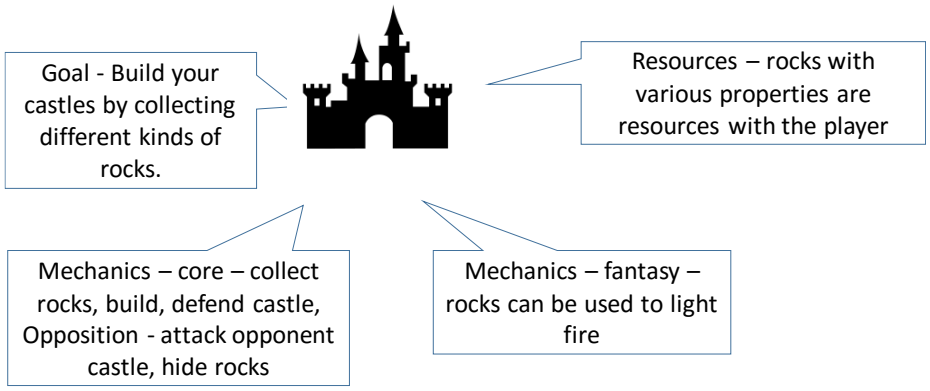


Figure 3.10 Schematic for Rocks Game

In the third approach, participants looked for striking features and the highlights of the content. This includes searching for ‘happening’ things or movements, for example, the flow of current in the ‘electric current’ topic. Striking features can also include contesting elements e.g. opposite pairs such as heat and cold in the ‘Heat’ topic.

Apart from the strategies, in this stage of content exploration, participants performed activities such as chunking and selecting sections of the topic, or compiling a list of elements at the end. The content exploration strategies enabled seeking of game like elements in the content, as advised in Klopfer et al. [2009] for realizing endogenous design. The content exploration strategies are in a way similar to the information gathering strategies employed by designers for searching relevant sources of inspiration for the design [Mougenot et al., 2008].

**Core Ideation**

Participants start thinking about game ideas after the initial content exploration. They explore multiple gameplay possibilities in relation to the extracted content elements. The gameplay ideas initially come from already known gameplays.

Generating ideas from prior games is a known approach, but it may lead to lesser novelty [Hagen, 2004]. Designers generate ideas using various techniques in which they are comfortable. However, discussion on ideation techniques is beyond the scope of this thesis. Though participants began mostly with known gameplay ideas, we observed that novel gameplay ideas emerged when they relook at content elements for translation. A common observation is that the core idea, and hence the game design, evolves gradually through an iterative process as indicated in figure (3.11). Versions v1, v2, v3 indicate the evolution of idea. The initial idea is generated in v1, revised in v2 and firmed up in v3. It can be observed from the temporal view that the ideation stage is not a single block but it is spread across.

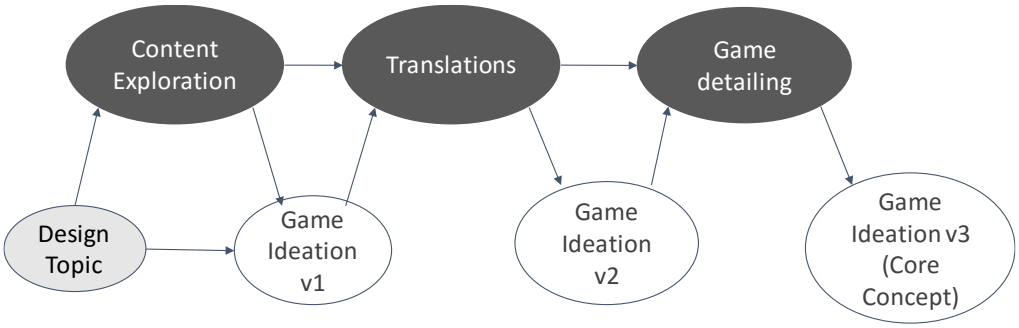


Figure 3.11 Typical Design Process (Observed)

The core ideation stage also involved deciding the structure of the game. This includes the core movement (gameplay) and the gameworld. Decisions regarding the gameworld include the plot, theme, narrative, and the setting. Since these elements have some overlap, we observed that such decisions were taken in concurrence with each other. Some participants created replicas of the real world (simulation) at the first instance, since simulations were easier to synthesize. Later, fantasy elements were added to the simulation.

These findings are consistent with observations made by Ke [2016] on themes of integration. Ke indicates three ways of structuring a game. These are conceptual representation, simulation, and contextualization. Conceptual representation is the embodiment of concepts (objects and its properties) to create a representation in the game world. Contextualization is the act of creating a fantasy world and situations within them. Table (3.7) indicates examples of the gameworld created by the participants using the elements of content. The table also indicates the real and fantasy elements of the gameworld generated from the content. We can also note how personification was used in fantasy world (contextualization).

Table 3.7 Game World Ideas

| Topic | Reality | Fantasy | Translation strategy |
|---|---|---|---|
| Rocks and Soil (Main study) | Search Rocks, Build Castles, Throw stones to destroy castles | Stones can vanish | Mixed (simulation, contextualization) |
| Heat (Main study) | Use heat to expand, cold to contract | Heat & cold monsters who block path | Contextualization using Personification |
| Traffic (Pilot 1) | Follow rules | | Simulation |
| Basic Shapes (First hand) | Lines and shapes forms shapes | | Conceptual representation |
| Force (Workshop topic) | Move objects | | Conceptual representation |
| Fundamental rights (Main study) | Face situations, use right | Terrain hurdles | Contextualization |
| Mensuration (Main study) | Add areas and calculate | | Conceptual representation |
| Digital Banking (Pilot 2) | Trade, produce, consume goods and exchange money | Village marketplace | Simulated Contextualization |

Game goals were decided as part of the core idea. These goals were derived from the educational topic or decided based on the choice of narrative in the gameworld. After the gameworld and the goals were decided, it helped in creation of a path towards the goal. However, making final choices about the path or core movement was hard unless the mechanics and resources were decided. The gameplay could not be finalised and the decision was parked until the translation stage was completed. Therefore, conceptualization continues after the translation stage. In summary, in the ideation stage, strategies for the gameworld creation were observed and some initial steps were taken toward generating the gameplay.

**Content to Game Translation**

After deciding the rudimentary game idea, participants looked for methods to translate content elements to game elements. In the translation stage, the elements extracted from the content were reimagined as game elements. Typically, the first element reimagined became the anchor element for translation. Often, the anchor element was a ‘resource’. Real world objects or even abstract concepts were transformed to game resources. For example, in ‘rocks and soil’ topic of geography, rocks were translated to game resources and then interactions such as acquiring, trading, using them to construct, attack etc. come to fore. Similarly, in fundamental rights, rights become the resources.

Mechanics was another common anchor. In the first strategy for mechanics, designers enlisted actions that humans can perform with the resources. The second strategy to design mechanics was to map one of the known mechanics to the content elements. When the participants observed that obstruction or opposing force was more prominent in the content, they started with an opposition mechanic. When the resources or mechanics emerged from the content, the design became endogenous. When the participants were unable to synthesize a mechanic or resource using content elements, they tended to choose a standard fallback mechanic such as a race. Such choices led to exogenous designs. Translation, together with exploration, played a major part in endogenous design.

After the core or opposition mechanic was selected, participants worked to complete the system of mechanics. The core mechanic, opposition mechanics, and satellite mechanics comprise this system [Fabricatore, 2007]. Participants spent significant effort in designing the system of mechanics. This was natural, because amongst the three key components Mechanics-Dynamics-Aesthetics (MDA) of the game system, designers directly control mechanics design [Hunicke et al., 2004].

Participants often struggled to identify a suitable opposition mechanic when it was not prominent in the content. In such cases, they used exogenous opposition mechanics. However, few participants also took this as a challenge to generate novel ideas for opposition mechanics. In the game of ‘mensuration’, the main mechanic was to claim ‘areas’ on the grid by placing available shape tokens. The participant came up with a novel idea of holes (shapes that represent holes) as an opposition mechanic. In figure (3.12), a red (dark) square is placed on a blue square creating a hole. This reduced the area claims and the score of the player with blue token.

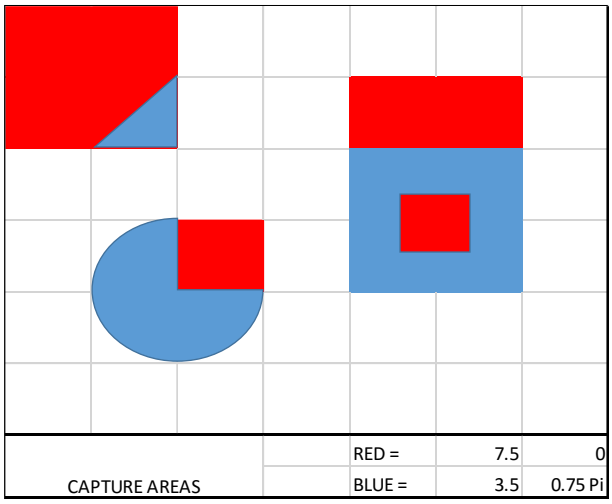


Figure 3.12 Schematic of Mensuration Game

Table (3.8) enlists examples of how the system of mechanics emerged from content elements in various topics. The 'possible actions' column indicates the source element identified by the participants for translation to mechanic. Satellite mechanics were added to support the core mechanic and were not necessarily endogenous. The fallback mechanic was used when the participant was unable to generate a core mechanic from the content. It is added in the table to indicate the thinking process (of the participants) for generating core mechanics.

Table 3.8 Generating Mechanics

| **Topic** | **Possible Actions** | **Core mechanic** | **Satellite mechanic** | **Opposition mechanic** | **Fall back mechanic** |
|---|---|---|---|---|---|
| Rocks and Soil | Rocks can be assembled, thrown | Build, Assemble, Dig | Attack, Capture | Block, Destroy | Collect rocks and Race |
| Fundamental Rights | Rights need to be protected | Protect, use | Move | Situations that affect rights | |
| Heat | Heat expands material and cold contracts | Expansion and contraction | Move | | |
| Mensuration | Areas | Arrange | Capture | Break (use of holes in area) | |
| Traffic awareness | Movement | Race | Escape | Block | |

When the content is effectively translated to game elements, learning is actuated through these elements. The learning can happen through visual elements (layouts, objects, tokens etc.), action elements (mechanics), information elements (cues and cards), decision elements (player choices) and others. In terms of designing games for knowledge application versus knowledge acquisition, our studies concur with Ke's findings [2016]. Designers focus more on prior-knowledge activation as compared to novel knowledge acquisition.

Designing games for new knowledge acquisition is not easy. For example, in the case of designing game for 'heat', the participant could not easily decide how to give that sensation of heat to the learner. She thought of using physical objects and actual burners for the purpose. Some participants resorted to using animations, while few considered analogies. In summary, using games for introducing new concepts is not easy and may not even be possible in some cases.

Though the strategies for translation of content elements to game elements are situated in the domain of educational game design, we explored whether translation strategies are available in other domains. One such case was some recent work in the literature on text to image translation, using deep machine learning. The two steps in image translation are feature extraction (identifying elements in the text) and mapping. An algorithm maps extracted elements to an available library of image components. Similar approaches can apply to educational game design, in future, for automatic extraction and translation of content to game elements.

**Core Ideation - Again**

After the translation stage, participants iterated with ideation stage as indicated in figure (3.11). They reworked on earlier rudimentary ideas. In the second pass of ideation, the path, movement was finalised, player interactions were decided and the concept was almost ready.

**Game Detailing**

In the game detailing or elaboration stage, participants revisited earlier design decisions and attempted to finish the design of the remaining components of the game. The detailing stage predominantly included activities such as:

a) Defining rules for starting, progressing, ending and scoring in the game.
b) Checking and introducing elements for fun such as curiosity, chance, entitlements, traps etc.
c) Introducing events and rules that influence game dynamics.

We found that participants took the detailing decisions using knowledge of prior games as well as clues available in the content elements. In the ‘fundamental rights’ game, the participant took a cue from prior games and created a hexagonal board with a physical terrain that restricted player movement. A layout inspired by the content, such as a board depicting the political terrain of a war-affected country, could have led to endogenous design.

It was also observed that participants detailed only one case where there was repetition. For example, in the case of the game on ‘chemical reactions’, participant detailed only one case and decided that the rest of the cases would follow the template of the first case. In summary, the detailing stage has strategies for completing the missing elements.

**Core Ideation Again**

Participants frequently verified how their design decisions affected scope, scalability, endogenousness, learning transfer, fun, and complexity. However, in the end they did final verification. They used mental play for verification of game dynamics. In mental play, the designer plays the game in the mind to identify loopholes in the design. Participants also verified the content coverage and reworked on the design to accommodate additional elements.

**Meta-Strategies**

'Meta-strategies' cover the sequence and approaches for using the rest of the strategies. Though every participant followed a different sequence in performing design activities, there was commonality in a broader sequence, as indicated in figure (3.11). We observed two approaches to managing scope and coverage. Some participants first determined the gameplay and then fitted the possible learning content within it. Others decided the scope and then chose the gameplay that could be accommodated in the scope.

Regarding decision of gameplay, we found two approaches. First was a conservative approach where participants selected a known gameplay. The second was an open approach where participants waited for the elements to emerge and then decided gameplay. Each of these choices affects the quality of the design. Known gameplays naturally lead to lesser novelty and are less likely to create endogenous design.

## 3.10.1 Impact of Content Type and Designer Capability

In the preceding section, the emergent strategies across the participants and topics, were discussed without specific attention to the variations based on type of content (factual, procedural, conceptual) and designer ability (novice, trained, experienced). We discuss these variations further.

**Variation Based on Designer Background**

Extraction: Participants who were trained in design schools, showed a knack for extracting peculiar elements from the content. Participants who had worked in digital game design studios seemed to treat all kind of content as a set of blocks, which will be plugged into a digital narrative.

Gameworld creation: Participants with no background in game design, typically created simulation based gameworld. Simulation worlds are easier to create as compared to other types. Participants with digital game design experience mostly started by creating a fantasy world with a story, characters, and puzzles inside it. Participants with background in table-top games focussed on objects and properties, and began with a physical representation.

Movement: Participants from all backgrounds struggled with design of movement and opposition mechanics. Identifying the element that moves, changes hand or takes game to the next state, was not easy. During synthesis of our framework, we explicitly added a strategy to address that. Generating ideas for movement required creative ability of the participant.

Opposition mechanics: Designing opposition mechanics is a peculiar challenge in serious games. There may not be easily identifiable opposition. In the fundamental rights game, the participant created a core mechanic as ‘use of right’ to overcome situations. He created a hexagonal board in which the movement was through the cells. The movement is not necessarily related to topic. The opposition mechanic was created as a set of difficult situations. Some cells posed opposition due to the terrain. In the traffic game (pilot study) as well, participant had difficulty in designing movement and opposition mechanic. If complying with traffic rule was essential to move forward in the game, incentives to break the rules were necessary to create opposition. However, this would conflict with the purpose, authenticity and ethics of learning. Hence, opposition mechanics are difficult to design in serious games.

Convergence was another area where most participants struggled, irrespective of the background. Performing activities like systematic exploration, convergence depended on individual disposition and discipline rather than experience.

**Variation Based on Content Type**

Each type of content and each topic within it offers unique advantages as well as challenges for translation to game. In factual topics, we had included ‘rocks’ from geography and ‘fundamental rights’ from civics for design. Designing games for the ‘rocks’ topic was much easier as it offered objects, properties and varied possibilities about what could be done with them. The ‘rights’ topic did not have obvious elements and participants struggled to get quick ideas. One participant created a digital game having narrative, characters and situations. In such a design, the content is not translated to the game but merely used in solving the quest.

It was observed that participants found it bit hard to work with conceptual topics such as electric current and heat. This was not because the topics did not offer elements, but because the concepts were intricate to understand and truthfully translate. Procedural topics were relatively easier to translate as they offer a sequence of actions. We can infer that the presence of easily identifiable objects and sequences, offer easy translation to game. For topics that do not, designers need to spend more creative effort for achieving endogenous designs.

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**Summary of Chapter**: We extracted, analysed, and categorised the strategies for endogenous game design using appropriate methodologies. The strategies discovered through our research can be utilised effectively when presented in a cohesive, interconnected fashion. A design framework can offer such an integrated view. The development of the framework is discussed in the next chapter.

# Chapter 4 **Endogen Framework**

The knowledge harnessed from our studies can be represented in a descriptive form such as an ontological structure or a directory of strategies. New knowledge in the descriptive form makes useful academic contribution. However, the descriptive formats are translated into prescriptive models/methods/frameworks for better consumption in practice. Therefore, we aimed to synthesize a framework of the discovered strategies. In this chapter, an approach to synthesize the design framework is presented and the emergent framework is detailed.

## 4.1 Approach to Synthesis

The strategies identified in Chapter 3, offer greater practical value when they are integrated, organized and presented in a coherent format. A model, method, theory or framework is typically used to create coherence and describe the interconnected concepts. To represent our work, we chose the framework as it gives a notion of flexibility and adaptability compared to a model. *A conceptual framework is an integrated view that brings together a number of related concepts to give a broader understanding of the phenomenon of interest* [Imenda 2014, Liehr and Smith 1999]. This definition suits our purpose. In order to decide the approach to synthesize our framework, we evaluated the literature for the prevalent practical and theoretical approaches.

**Brief Review of Existing Frameworks**

We searched papers that describe design models, methods, and frameworks in the field of educational game design. Some of the models are discussed earlier in section {2.4 and 2.5}, but here the focus is on the approach to synthesis. It was observed that most papers describe the purpose and structure of models, but not the approach and rationale for development. For example, the paper on Serious Games Design Assessment (SGDA) [Mitgutsch and Alvarado, 2012], describes the components of the framework without detailing how it was developed.

In the papers that explain the development of models, two kinds of approaches are observed. The first is a ground-up approach in which models are constructed by using atomic elements. The second is a derivative approach in which new models are created by extension, specialization, combination and mapping of existing models. An example of the derived models includes the Design-Play-Experience model. It is a specialization of the Mechanics-Dynamics-Aesthetics model [Winn, 2009]. The RETAIN model built by combining elements of Gagne and Kellars models [Gunter et al., 2006] as well as the LM-GM model created by mapping the pedagogic and game elements [Arnab et al., 2015] are some other examples.

The model for the design of persuasive games [de la Hera, 2012] is an example of the ground-up model. This model is built using three facets of persuasion: purposes, assumptions, and structures. The visual representation has three concentric layers representing levels of persuasion – signs, systems, and contexts, with each layer having multiple dimensions. The model guides designers to analyze as well as synthesize elements of persuasive games.

Another example is the Applied Game Design Model, proposed by Deen [2015] for integrating content in the gameplay. His approach to development is through building a sequence of steps created by breaking down learning process. He then introduces a new step for transformation of content elements to game elements. The model is iteratively improved through prototyping and feedback. We also found few other examples of ground-up models. The Tangible User Interface Design Framework for learning, which is made of taxonomy of elements and a set of guidelines to design these elements [Antle and Wise, 2013], and the design framework for embodied learning games and simulation, created from design dimensions discovered through literature survey [Melcer and Isbister, 2016).

One more example of ground-up development is Serious Games Framework (SGF) proposed by Hall et al. [2014]. Their approach to developing the framework is through use of existing literature in the fields of learning motivation and game design. The framework is derived through deconstruction of game system into elements having pedagogical qualities. The structure of framework is a collection of resources arranged logically. It is further evolved through iterative validation, carried out using case studies. This framework consists of a conceptual layer, a design process, a set of activities within the process, and supporting tools.

Derived models are relatively easier to develop and validate because the underlying models are already established. Ground-up models, which are developed using basic building blocks, have to demonstrate the soundness through principles of organization. Ground-up models need an iterative approach where the users or experts validate each version. The improvisations lead to maturity over a period. Our proposed framework is developed using such a ground-up approach.

**Theoretical Approach to Development - Models of Design**

According to Blessings and Chakrabarti [2009], a typical characteristic of design research is that it aims at understanding the phenomenon of design and uses this understanding to prescribe a new or better design process. Design research is classified, therefore, into a descriptive part, which deals with collecting and systematising current knowledge, as well as a prescriptive part, which deals with creating a theory or a model of new knowledge that designers can use in practice [Vermaas, 2014]. Transformation of descriptive knowledge into prescriptive forms is achieved through synthesis of models or frameworks.

The distinction between a theory and model is not always clear. Chakrabarti et al. [2016], after studying several theories and models of design, posit that a design theory is a body of knowledge consisting of a set of constructs and relationships between them. Goldschmidt [2014] clarifies that a model "is a simplified and schematic representation of the essence of a theory". A model represents a theory through its constituent parts and relationships among them. The purpose of such 'models of design' is to explain the process of designing and the elements within. Models of design can explain how designs are and designing is, as well as how it should be. Prescriptive models are usually based on a methodological sequence of design stages and activities. These are considered to represent improved processes that are more effective and efficient [Gericke et al., 2012]. Our aim is to develop such prescriptive 'model of design' in the form of a framework.

**Developing a Framework**

Kannengieser [2009] provides a good account of how design methods (models/frameworks) can be developed using the Function-Behaviour-Structure (FBS) approach. The function indicates the utility of the framework, which is defined first. The structure represents the internal composition, created to achieve the function, using either the ground-up or the derived approach. Behavior is articulated through the expected qualities exhibited by its structure.

Existing literature [Chakrabarti and Blessing 2016, Van Boeijen et al., 2015] highlights the commonality of functions and behaviors of design models. The guidance on structure of the model can be derived from the works of Blessing and Hubka [1983]. The connections between function, behavior and structure can be developed through experience, experiments, or hypothetical causal models. We employed the FBS approach and supporting literature to articulate the organizing principles for developing our framework. The principles are as follows:

**1. Functions of a Framework**

a) The primary function of a framework is to provide explanation and direction for practice. It should act as a tool for decision, control, communication and learning for designers [Koskela et al., 2014].
b) Provide guidance to the designer during design and support interaction between designers [Eckert et al., 2003].
c) Help in reminding the designers of essential steps, achieving goals without too many detours, and communicating with stakeholders more easily [Van Boeijen et al., 2015].
d) Bring structure to the designers' thinking and actions to help them from getting overwhelmed with complexity [Van Boeijen et al., 2015].

**2. Behavior or Characteristics of Design Frameworks**

The behavior of a framework is represented through the qualities it exhibits. Commonly expected behavior of a design framework includes:

a) Purposefulness: It should provide intended utility as follows:
    i. Enable the desired function.
    ii. Include supporting functions and process.
    iii. Be usable for intended audience, in the context of use.
b) Boundedness: It should have a defined boundary about what it can do and what it cannot.

c) Flexibility: It should not be so rigid that it does not allow any freedom to the designer and not be so slack that it compromises the stability to approach.
d) Extendibility: Designers should be able to extend the framework for additional purposes [Van Boeijen et al., 2015].

The expected behavior of the framework is better articulated before the structure, so that the structure is created to exhibit expected behaviors.

### 3. Structure of Design Framework

The structure of the framework consists of the internal components, interconnections, and the visual manifestation. The guidance available for developing a structure is discussed here:

**Building Blocks:** Gericke and Blessing [2011] deconstruct the design process into stages (phases), activities, and strategies. The process has three stages: a problem definition stage (set of requirements), a conceptual design stage, and a detail design stage. Similarly, the often-cited product design process by Pahl and Beitz [2013] has these three phases: clarification of the task (problem definition), conceptual design, and detail design, but it also has Embodiment design as an additional phase. In general, the literature on design processes concurs on these stages.

A design activity is a finer subdivision of the design process, which can recur several times in the same process [Gericke and Blessing, 2011]. The third facet of process is the strategy. Gericke and Blessing [2011], describe design strategy as the sequence in which design stages and activities are planned or executed. This notion of ‘strategy as an overall plan or sequence’ is common in design literature, but we have deviated in defining it. We have adopted an inclusive, broader definition in which the design strategies include the methods, principles, steps, and tactics of design.

Hubka [1983] also provides guidance toward building the structure of design process. According to him, the structure consists of partial processes, phases, and detailed design steps. In order for these processes to progress toward the goal in a systematic way, methods, rules or working principles are required. He defines the system of design methods and working principles as 'design tactics'. A summary of literature thus indicates that the framework typically consists of a process that has stages, steps, and strategies.

**Manifestation:** Schell [2014] comments that "many game design books have an incomplete feeling to them, the reader sees a lot of interesting things, but can't really comprehend how they all fit together". A binding layout or arrangement can bring the necessary cohesive appearance. The arrangement of the building blocks can take many shapes such as waterfall, spirals, tetrahedrons, trees, tables, catalogues, etc. based on the nature of the content. Synthesizing the shape of the framework includes a) deciding media (digital, physical etc.), b) creating a layout of components that depict connections and flow, d) providing instructions for use, e) visual design and f) creating supporting material.

Inspiration from existing frameworks can also help in manifestation. The compilation of design methods [Delft Design Guide by Van Boeijen et al., 2015] has many ideas, for example, the flowchart structure of the Pahl and Beitz [2013] model. However, the quadrant model by Kumar [2012] for 101 design methods was found to be a suitable reference. Kumar classifies the steps in the innovation process in seven stages laid out in four quadrants (figure 4.1). Kumar's model indicates a way to arrange the steps and stages in a less rigid, easily consumable format.

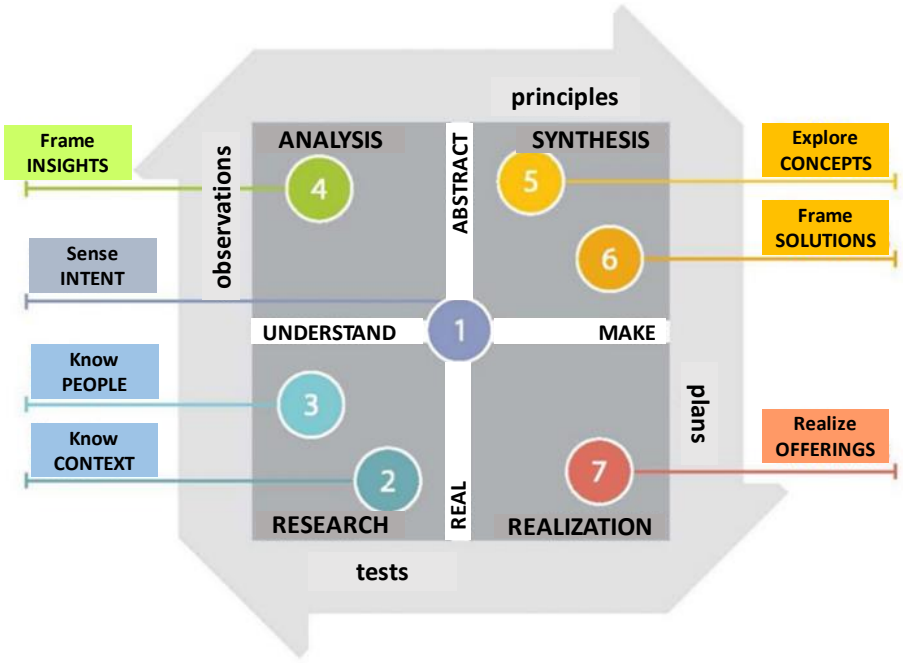


Figure 4.1 Kumar's Quadrant Model

4. **Summary of Guidelines for Synthesis**

Based on the survey of these practical and theoretical approaches, we gather the following guidelines for synthesis of proposed framework:

a) The function of a framework is to provide explanation and direction for practice; in our case, it is to guide game designers toward achieving endogenous design.
b) The behaviour i.e., the expected qualities of a framework should be defined upfront and validated after synthesis.
c) The structure of a framework consists of stages, activities, and strategies. The creation of structure (using ground-up approach) begins with identification of the building blocks. In our case, these are the strategies discovered from our studies.
d) The development of framework begins by defining the function of a framework, then defining the expected behaviour and finally building the structure. The connections between function, behaviour, structure are developed through experience, experiments and hypothetical causal models. An iterative process, which considers user feedback, is necessary for development of ground-up frameworks.

## 4.2 Synthesis of Endogen Framework

Before synthesizing our framework using the guidelines discussed in the preceding section, we give identity to the framework and state its purpose.

**Identity**

The framework is named as 'Endogen'**.** Endogen is coined from the words **Endo**genous **Gen**eration. The name of the framework indicates the focus of the framework on generation of game elements from within the content. The dictionary meaning of the term endogen in biology is 'a plant that develops by internal growth'. The Endogen framework aims to help games germinate and grow from within the content. Further, we have chosen to call it a framework and not a model or method, as it implies a less rigid representation of interconnected concepts, which is open to adaptation by practitioners.

**Purpose**

The Endogen framework is intended to be a toolkit to aid educational game designers in endogenous design. The framework is primarily aimed at novice designers and students, who have basic knowledge of game design concepts, but need step-by-step guidance in educational game design. Therefore, it is essential that the framework include a design process. The discovered strategies would be organized as part of the process, to help designers along the way. Experienced designers may choose selected strategies instead of using the entire process.

The synthesis of function, behavior and structure of the framework is discussed next.

### 4.2.1 Function of Framework

The function of the Endogen framework is to enable creation of endogenous design by:

a) Acting as a guided path for end-to-end design activity
b) Offering a set of strategies that can be used at each step in the path
c) Acting as a reference as and when needed

The framework is intended to help designers in preparation, exploration (of elements from the content), core design, translation (of content elements to game elements), elaboration and verification of design. The strategies will presently cater to games for middle school topics (as mentioned in the scope), but the users can try these for other segments.

### 4.2.2 Behavior of the Framework

The proposed framework is expected to meet following behavioral qualities:

a) Facilitate overall game design process with guidance at each step.
b) Facilitate endogenous design creation through specific strategies.
c) Afford suitability for users with varying usage conditions (users with varied backgrounds, different periods of usage and for varied type of content).
d) Provide flexibility and ease of use. Designers should be able to use the complete process or just the selected strategy and steps. Framework should not need much effort to learn.

This behavior was achieved through creating a suitable structure that affords such behavior.

### 4.2.3 Structure of the Framework

The structure of Endogen framework consists of two parts, external manifestation and internal components/building blocks arranged into a process.

**Manifestation**

The framework is created as a physical board, a set of cards, necessary instructions, checklists and rubrics. A digital version is possible but not in the scope of the thesis. The internal layout is defined by the process, which is discussed next. The framework is developed as a single version catering to all types of users.

**Building Blocks**

The building blocks of the framework are the design stages identified in the previous chapter {Section 3.10}. Specifically, these are a) Exploration, b) Ideation, c) Translation, d) Elaboration, and e) Meta-strategies. These categories and the strategies within identified in previous chapter {Section 3.10}, form the initial building blocks for developing the Endogen framework.

**Process and Layout**

A prominent sequence of stages observed in our studies is indicated in figure (3.11) {Section 3.10}. According to that sequence, the game concept is gradually developed through stages such as exploration, translation and detailing. The ideation stage appears multiple times between other stages and doubles up as verification gate for earlier idea. This emergent sequence was used as a starting point for developing our framework. The identified stages are comparable with the problem identification, conceptual design and detailed design stages in the Blessings General Design Process [Gericke and Blessing, 2011]. In our case, the problem definition is partly in the design brief and partly in the content exploration stage. The conceptual design is the game ideation stage and the translation stage is a fresh introduction.

The initial sequence discovered in figure (3.11) was modified to attain consistency with the iterative nature of the game design process. We also experimented by placing the game ideation stage after exploration, instead of multiple places indicated in the discovered sequence, so that designers could make decisions at one place. The box for meta-strategies was positioned at the centre. The first version of the modified flow is indicated in figure (4.2).

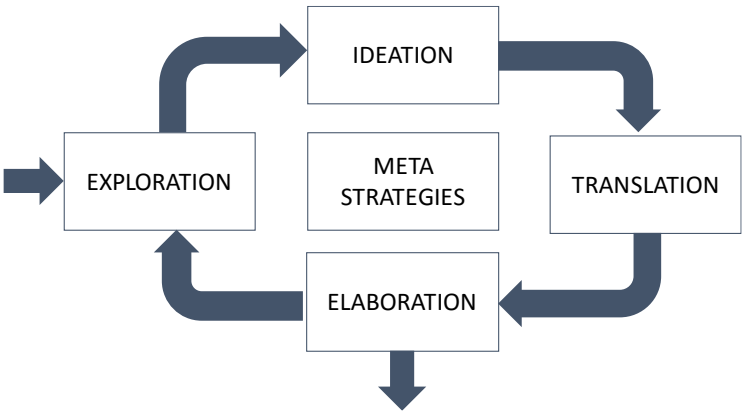


Figure 4.2 First Process Flow

Using this first process flow, the first version of the framework was created. The orientation and visual appearance of the framework was inspired by the game of Ludo, which has four quadrants as in figure (4.3).

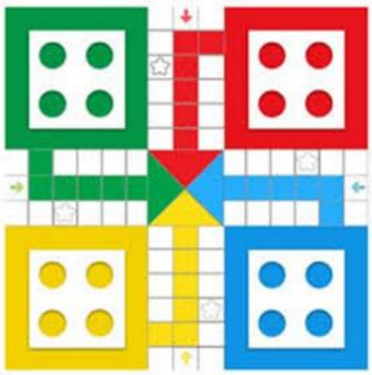

Figure 4.3 Inspiration from Ludo

The sequential stages of the process were arranged in four corners and the fifth block was added at the center for strategies that are common to all. Verification and meta-strategies find a place in this central block. The internal details of each stage include the input, strategies (with sequential numbers) and output. We created four different types of cards to support each element on the layout. These were initiation, activity, strategy, and outcome cards.

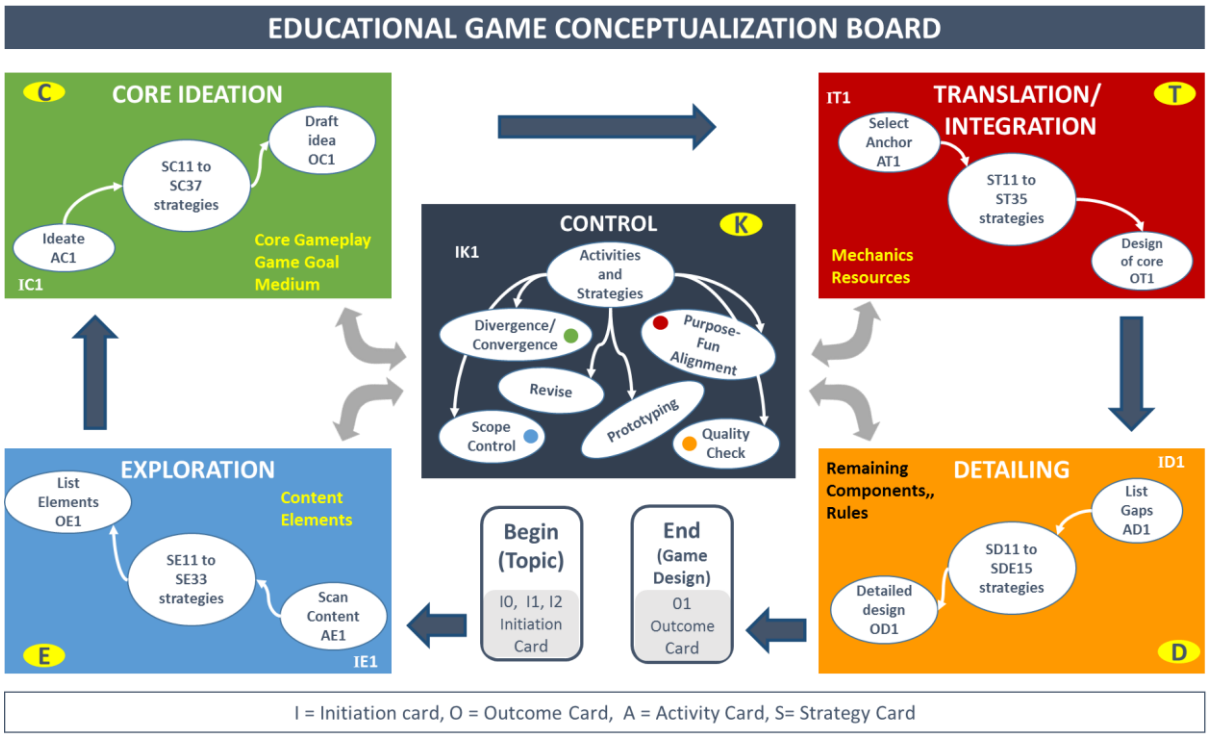


Figure 4.4 First Layout of Framework

The first layout of framework was piloted with a small set of users. It was found that movement through the central block was confusing. In addition, the multiple types of cards appeared overwhelming. The board did not give much information other than the name of stage and the numbers. Also, the iterative nature of the process was not coming out as the iteration was through the central block. These and other flaws in the process, language, and usability were identified. This necessitated revision of the process. The changes were made as follows:

a) The common steps including the meta strategies in the central block were assigned to respective stages.

b) A separate verification stage was created at the end.

c) The places for translation and ideation were exchanged.

The modified process is shown in figure (4.5)

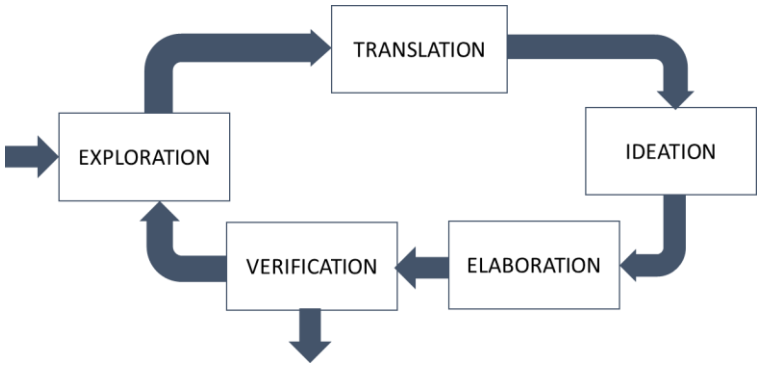


Figure 4.5 Second Process Flow

Based on the second process flow, a new version of the framework was created with a visual representation as shown in figure (4.6). The lacunas in the earlier version were corrected as follows:

a) Each stage now indicated the name of the step rather than just the numbers.
b) The iterative nature was now prominent. The framework now gave a notion of 'movement' where the designer could move from the start, through the stages, to the end.
c) We now classified the steps into just two types: strategies and activities, with each step supported by its respective card.
d) Some more changes were made, such as renaming Ideation to Core design, and addition of preparation steps before the main stages.
e) Fast track option was provided through legend.

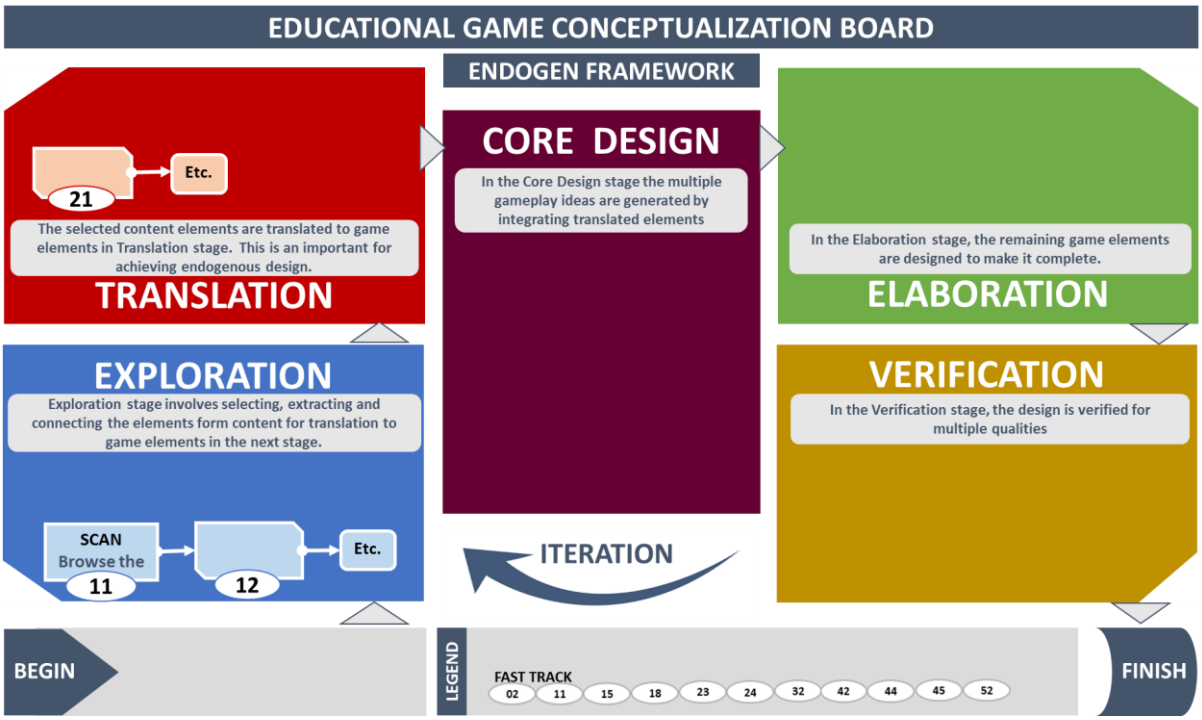


Figure 4.6 Second Layout of Framework

Again, the second version of the layout was tested with a sample of users. Keeping the core design (game ideation) as one monolithic block was identified as a mistake. It was necessary to break the core design stage into atleast two parts. Therefore, a third version of flow was attempted as shown in figure (4.7). The core design stage was split into two parts – design divergence and design convergence. The translation stage was placed between the two. This was inspired by the Jones design method [1992], which has three stages: divergence (generating solutions), transformation (refining, transforming alternatives) and convergence (eliminating, selecting solutions). This flow stays as the final version in this thesis.

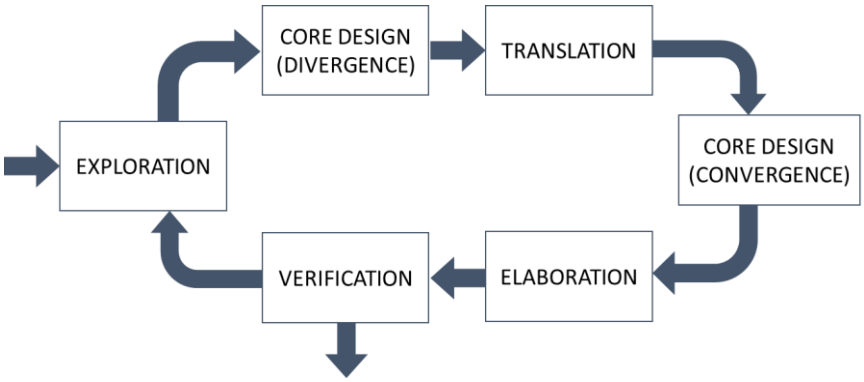


Figure 4.7 Third Process Flow (Final)

The final list of stages is indicated in table (4.1). A reflection stage was added at the end.

Table 4.1 Final List of Stages in Framework

| | **Stage** | **Activities** |
|---|---|---|
| **1** | Preparation | The designer acquires the design brief and prepares for designing. |
| **2** | Exploration | Selecting, extracting and connecting the elements form the content. These elements act as candidates for translation to game elements. |
| **3** | Core Design - Divergence | Ideas are generated for base elements of a game. The base components include the game world and the movement. |
| **4** | Translation | The selected content elements are translated to game elements such as mechanics and resources. |
| **5** | Core Design - Convergence | The game concept is finalized. |
| **6** | Elaboration | Remaining game elements are added to make the design complete. |
| **7** | Verification | The design is verified for its completeness and other qualities. |
| **8** | Reflection or Iteration | After the verification stage, the designer can continue to design iteratively or proceed to reflection and closure of the design activity. |

This process flow with eight stages led to a newer version of the framework as depicted in figure (4.8). The visual layout retained the notion of ‘movement’ and the iterative process.

Few other changes were made to visual layout as indicated further:

a) The steps were numbered sequentially from start to end rather than changing at each stage. Numbers would help designers visualize the relative progress.
b) Each stage was given a color code and a marked entry and exit point.
c) Dotted arrows were chosen between the steps to indicate that the flow was not rigid. It was to suggest that designers could freely navigate based on their own design preferences.
d) Mini loops were added to indicate iterations. Loops that required going back to the previous stage were shown simply by ‘go back’ boxes.

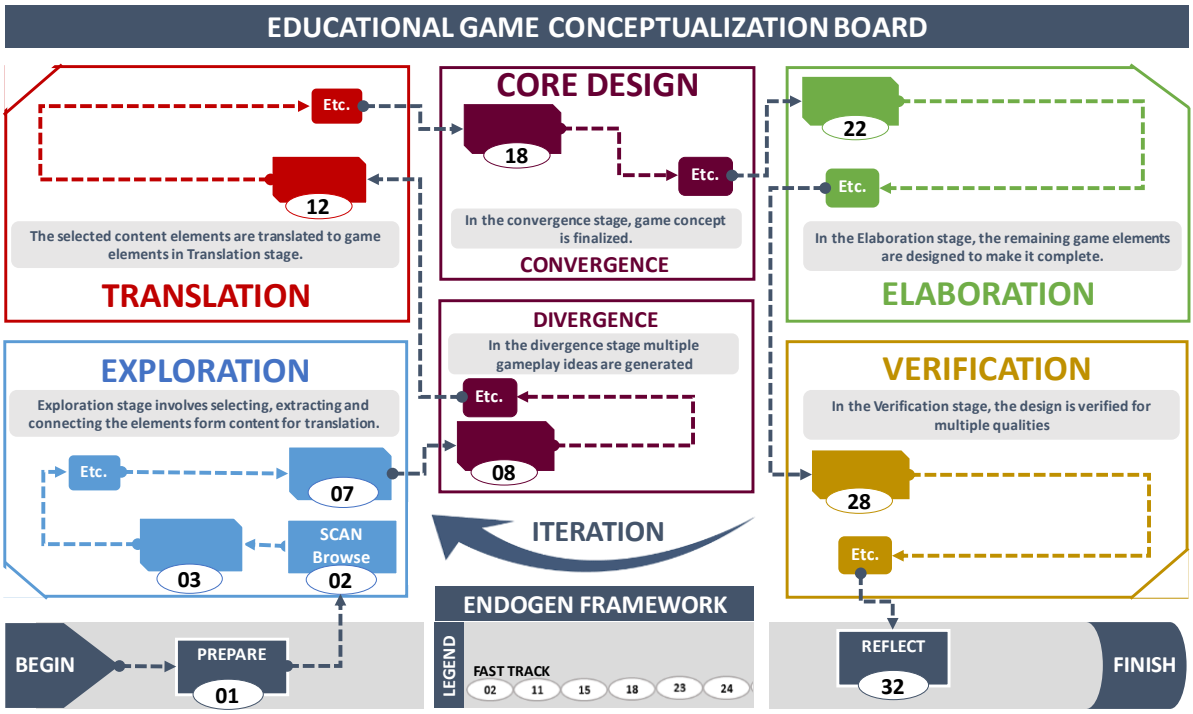


Figure 4.8 Third Layout of Framework

### 4.2.4 Final Layout

The early validation studies indicated that the details in the third layout of the framework were overwhelming and the process needed simplification. Therefore, a new radial visual layout was created without details, as shown in figure (4.9). The radial layout produces enhanced impression of circular 'movement' and the iterative nature of the process. Though not inspired by it, the structure of our framework resembles the circular structure of the game design process, by Dukes [1974]. The third process flow remains unchanged.

The exploration section of radial focuses on analysis, and the core design, translation stages focus on synthesis, followed by elaboration and verification. The arrangement of steps along the circular path makes tracing of the progress easier. The sequence of steps also underwent slight modification from earlier version. The details and internal loops excluded from the board were included on the strategy cards. This version stays as the final version of the thesis.


Figure 4.9 Radial Layout of Framework (Final)

**Strategy and Activity Cards**

Each step in the radial has a corresponding strategy or activity card. The card set is arranged by the numbers and carries color of the respective stage. The visual depiction has a subtle difference based on whether it is an activity step or strategy step. A strategy offers a way to do things and the designer has to use discretion. An activity is simply an instruction to do something. The visual difference is as shown in figure (4.10).


Figure 4.10 Two Types of Steps/Cards

The title on the card corresponds to title of the step. There is a short instruction below the title telling the gist of the card. The cards also have a symbol for ease of identification. When the designers use the framework a couple of times, they may simply refer to symbols. The main part of the card contains the specific guidance. For example, card no 14 in figure (4.11) guides the designer on strategies for generating mechanics and card no 16 is informs the steps to be performed in the activity 'review learning'. Details of each card are presented in section {4.3}

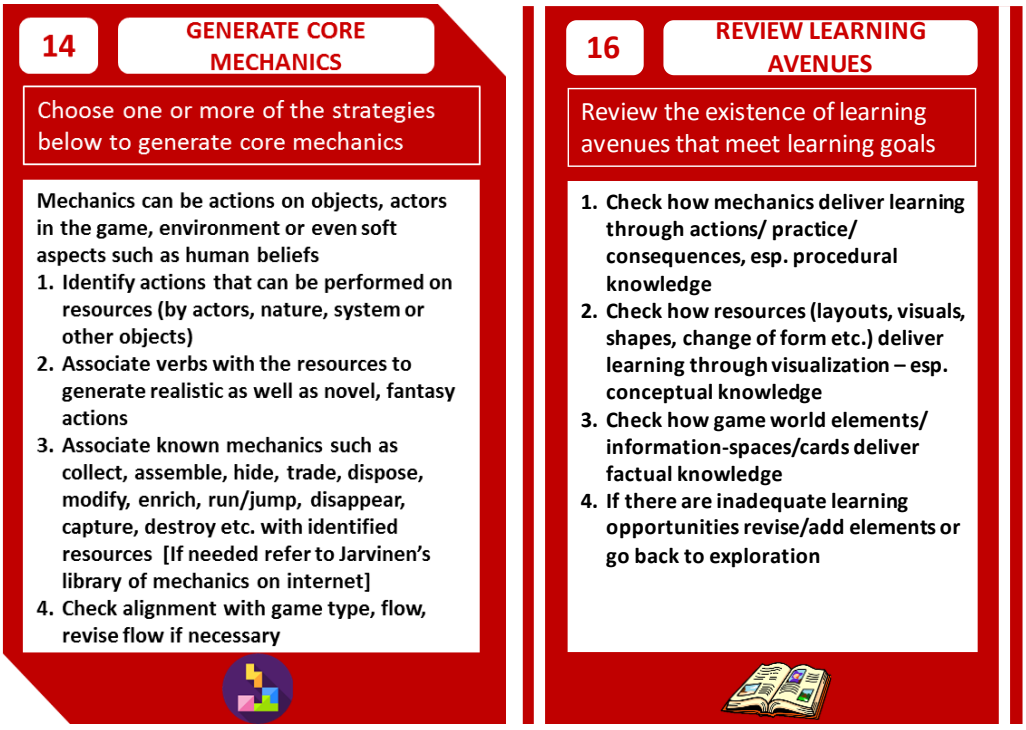


Figure 4.11 Strategy and Activity Card

**Additional Utilities**

The framework is supported by additional utilities, which we discuss later in section {5.2.1}.

Since the main constituent of the framework is the design strategies, we discuss each step in detail further.

## 4.3 Design Strategies

In the previous chapter, we discussed designed strategies in the form they were identified and observed in the data. These strategies underwent systematic appraisal before becoming part of the framework. While most of them became part of the framework without any change, some were combined or split. In some cases, details were added. New strategies were also added either to fill gaps in the continuum, and as extensions. We also derived few elements from the instructional design strategies discussed in Chapter 2. Design activities were included to make the process complete. The final set of 32 cards, one for each step, is discussed stage wise.

### 4.3.1 Stage 1: Preparation

Designer preparation is a short stage before exploration. There is a single step in this stage, which has activities. One of the prerequisites of using the Endogen framework is basic knowledge of game design and game terminology. The framework has a brief introduction to this and first-time designers can make use of it. Designers also need to acquire a design brief or decide the game topic and arrange for stationery and material for the design activity. The following tables provide details of each step.

| STEP 01 : PREPARE AND START | STAGE: PREPARATION |
|---|---|
| PURPOSE: Guides the designer to be aware of the prerequisites, acquire design brief, topic and required stationery | |
| GUIDANCE TO DESIGNER:<br>a) Become aware of game design principles, get acquainted with some existing educational games, read about endogenous design (available as part of framework)<br>b) Acquire the brief for design (the topic), learning objectives and reference material. Designers can select a topic by themselves if the design is self-initiated<br>c) Understand the learner profile (age, demographics) and the context (where the game is likely to be played, how many people will play it, likely medium of play etc.). This information can help in making early decisions regarding the medium of the game (digital, tabletop, physical etc.)<br>d) Organize material required for the design such as the stationery, laptop with internet and material such as cardboard etc. Any other objects such as toys, existing board games, colored papers, tokens etc. can be collected as a source of inspiration<br>e) Designers can take help of subject matter experts if the content needs explanation. Designers can invite potential players, and co designers as needed | |
| SIGNIFICANCE: Suggested preparation makes the design process smooth | |

### 4.3.2 Stage 2: Exploration

The exploration stage includes strategies and activities for understanding the educational content and extracting useful elements for translation to the game. There are six steps (02 to 07) in this stage. Exploration strategies are critical to achieving endogenous design.

| STEP 02 : SCAN AND CHUNK | STAGE: EXPLORATION |
|---|---|
| PURPOSE: Guides the designer to get an overview of the content and make segments | |
| GUIDANCE TO DESIGNER:<br>a) Scan the content, read through the brief and related material, understand various facets, get expert help if needed on the topic<br>b) Make logical chunks. Chunking is necessary to decide the scope for inclusion in the game. It is unlikely that the entire topic can be accommodated in the same game. In digital games, the chunks can be accommodated at different levels<br>c) Note whether the content has a lot of facts or procedures or theoretical concepts. This can inform the type of gameplay as indicated by Prensky [2001] | |
| SIGNIFICANCE: Chunking as a strategy helps define the scope | |

| STEP 03 : IDENTIFY CORE CONCEPTS | STAGE: EXPLORATION |
|---|---|
| PURPOSE: Guides designers to identify the core concepts or focal points of the topic | |
| GUIDANCE TO DESIGNER:<br>a) Identify core concepts. There can be more than one core concept in each topic. For example in the topic 'Force' in physics – the core concept can be force, acceleration, motion, Newton's laws etc. Sometimes the core concepts can be abstract, such as a bank account or banking transaction and it is important that they be identified<br>b) Identify relationships among the concepts, whether it is a cause-effect (e.g. Force and motion), hierarchy, a series of steps, circular, opposites, a matrix, a web, a pyramid etc. | |
| SIGNIFICANCE: The core concept selected here typically becomes the core learning from the game | |

| STEP 04 : EXPLORE SYSTEMATICALLY | STAGE: EXPLORATION |
|---|---|
| PURPOSE: Guides designer to explore all possible dimensions of the content | |
| GUIDANCE TO DESIGNER:<br>a) Identify Objects – in the content and their properties (physical/chemical/biological) E.g. weight, transparency, malleability, conductance, color/darkness, magnetic, heat, sounds/silence, codes, bonds, elasticity, brittleness, stickiness, shape, reproducibility, growth, decay etc., as well as the changes that can occur to the objects, arrangements of objects, their uses and so on<br>b) Identify elements in the environment – e.g. Spatial aspects (layouts, dimensions, views, blind spots, visibility), temporal aspects (events that occur over time, things that appear, vanish, change over time, fast forward, rewind, seasonality), movements (objects, particles, people, speed, distances, mode/vehicles), situations (conflict, tension, excitement, pleasure, rules, constraints)<br>c) Identify actors – agents that can make change to objects or environment – e.g. people or nature or systems, roles of people, goals of people, abilities, powers, possessions<br>d) Identify actions and interactions - such as what people do with objects, what they exchange with other people, what objects do with each other, what the environment does to objects etc. | |
| SIGNIFICANCE: The systematic exploration strategy reveals several content elements, which can be picked up later for translation to game design. This step also enables higher content coverage in the game and reduces the chance of missing certain aspects of the content. Systematic exploration is however, effort-intensive. Experienced designers may know the essential elements and hence focus on specific aspects rather than do systematic exploration | |

| STEP 05 : USE MULTIPLE LENSES | STAGE: EXPLORATION |
|---|---|
| PURPOSE: Guides designer to use specific lenses to explore content | |
| GUIDANCE TO DESIGNER: Use one or more of the following lenses:<br>a) Use Object-centric lens – indicates focus on objects and their properties. Objects and properties can be translated to game resources<br>b) Use Human-centric lens – indicates focus on human goals, actions, and exchanges. These can be translated to game goals and mechanics<br>c) Use Situation-centric lens – indicates focus on situations where the elements of the content can be used. Situations can be used in a game narrative | |
| SIGNIFICANCE: These lenses are useful when elements in the content are not obvious. Human-centric lens is useful in all topics, object-centric in physical sciences and situation-centric in social sciences | |

| STEP 06 : OBSERVE PECULIARITIES | STAGE: EXPLORATION |
|---|---|
| PURPOSE: Guides designer to identify the unique aspects of the content | |
| GUIDANCE TO DESIGNER:<br>a) Identify happenings, phenomena, things that move/change. For example, electric charges moving to form a current<br>b) Identify patterns – arrangements, steps, behaviours etc. For example, an array of equilateral triangles when arranged in a grid can lead to many more shapes such as parallelograms, rhombuses, trapeziums and hexagons<br>c) Identify contrasts, contradictions, contests – such as heat and cold, light and darkness, credit and debit, hard vs soft etc. These can help define opposition mechanics<br>d) Identify events/triggers that change the course – e.g., volcanos lead to formation of rocks<br>e) Use references. Often the examples in textbooks are pre-gamified content. These examples also highlight the peculiarities of that topic | |
| SIGNIFICANCE: This is a useful strategy to design novel game elements because it brings out elements, which are unique in content | |

| STEP 07 : CONNECT CONTENT ELEMENTS | STAGE: EXPLORATION |
|---|---|
| PURPOSE: Guides designer to connect content elements in several ways in order to get divergent game ideas | |
| GUIDANCE TO DESIGNER:<br>Connect the elements. Starting with simple lists or mindmaps, try to arrange elements in multiple ways. A simple connection diagram as indicated in figure (4.12) can help in game components such as players/avatars, goals, mechanics, resources etc. in next the steps | |
| SIGNIFICANCE: This is a critical step. The discovered relationships between content elements are useful in translation to game. | |

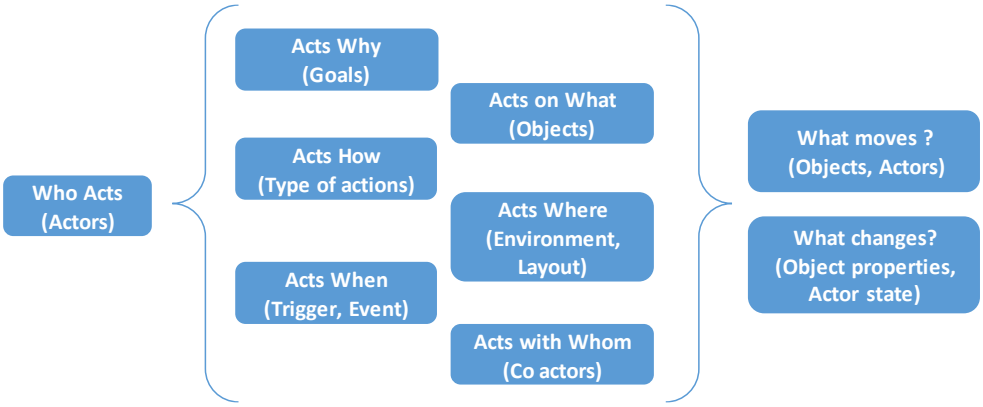


Figure 4.12 Meaningful Connections of Content Elements

During or at the end of exploration, designers may get initial ideas about the mechanics and resources. In such case, they may proceed to translation stage directly and later come back to core design. If not, designers can go through core-design divergence stage as per the process flow.

### 4.3.3 Stage 3: Core Design – Divergence

The design divergence stage is where designers are expected to generate multiple, though rudimentary game ideas, especially on the gameworld and gameplay. There are four steps in this stage (08 to11).

| STEP 08 : DECIDE MEDIUM OF GAME | STAGE: DESIGN DIVERGENCE |
|---|---|
| PURPOSE: Guides designers to decide the medium and configuration of game. The medium of game can be fixed by the designers right away once the brief is provided. However, the complexity of content can sometimes require choosing digital medium. | |
| GUIDANCE TO DESIGNER:<br>a) Decide the medium (whether digital or tabletop or a physical game) - The choice depends on where the game is expected to be played, economic affordability, access to digital devices and network, how many players will play together etc.<br>b) Decide the number of players –e.g. one player versus system, player versus player or team versus team. This decision can be revisited during convergence | |
| SIGNIFICANCE: Initial framing of medium and player configuration eases further choices. It is a principle of design by constraint. | |

| STEP 09 : IDEATE GAMEWORLD | STAGE: DESIGN DIVERGENCE |
|---|---|
| PURPOSE: Guides designers to generate ideas for the gameworld, narrative and the path | |
| GUIDANCE TO DESIGNER:<br>The gameworld can be created using one or more of the following strategies. Game world here means the setting, the background, the layout, the assets as well as the broad narrative in the game.<br>a) Create a simulation world – this world reflects the real world situations, objects and characters truthfully. Simulation worlds are easy to design but less fun<br>b) Create a fantasy world – a fantasy world can also be a metaphor/ analogy of the real world or an alternate world such future/history/aliens etc. Creating a fantasy, which can reflect elements of real world through analogy, is a better choice to achieve both endogenousness and fun. For example, to learn the concept of force, a designer may create a world where the player has to navigate a space ship between planets for some reason. A fantasy world can also be used to teleport content from one world to another. For example, the space world can be used to learn fundamental rights by saving the dwellers of the planets from rights abuse<br>c) Create a mix of simulation and fantasy – created by merging elements of real and fantasy world<br>d) Create representational world – when the content is predominantly physical/visual, such as in physics, geometry, geography, an object-based representation world can be created. Block games or board games typical have such representation worlds. For example, a game to learn molecules can have different atoms with slots and bulges to indicate vacancy or excess electrons in the outer orbit. These atoms can be plugged into each other to form molecules. The world here is a set of pieces | |
| SIGNIFICANCE: Initial decisions of gameworld eases further choices, which can be revisited later. | |

| STEP 10 : IDEATE GAME GOALS, PATH, MOVEMENT | STAGE: DESIGN DIVERGENCE |
|---|---|
| PURPOSE: Guides designers to generate ideas for the game goals and gameplay. The core movement in the game makes gameplay | |
| GUIDANCE TO DESIGNER:<br>a) Decide game goals - These goals can be derived from the content elements – especially the goals that human have in relation to the other elements of content. For example, in the topic heat, the goal of humans could be to heat or cool a substance or cook something, generate energy to move something and so on. These can be translated to game goals. It is not necessary that the goals should be of human beings. The objects can also have goals – e.g. they want to shrink or stick to a place or evaporate etc. The game goals should not be confused with learning goals<br>b) Decide movement – Deciding the core movement of the game (that makes the gameplay) is the key aspect of the design. The movement identified through exploration of peculiarities can be translated to the game movements. Note that the movement is not necessarily physical but some aspect that changes with time – it can be physical location, transactions, logical steps on paper etc. Examples of movement are charges move to form current, force moves objects, people can use rights to move through situations, geometric shapes can be created by drafting one side at a time (movement in terms of action steps), digital transactions can be done one by one, people can move on the map etc.<br>c) Ideate different layouts/paths through which the game goal is achieved. The paths can be linear, circular, zigzag, random, on the ground, in air, invisible and more. Designers can also borrow ideas from earlier games. | |
| SIGNIFICANCE: This step helps decides the core of the game or the gameplay. | |

| STEP 11 : LIST GAMEPLAY IDEAS | STAGE: DESIGN DIVERGENCE |
|---|---|
| PURPOSE: Guides designer to ideate gameplay by integrating gameworld, goals, path etc. The ideas can be skeletal at this stage without muscle. Since the game resources and mechanics are not yet decided, the gameplay will be complete in next steps. | |
| GUIDANCE TO DESIGNER:<br>a) Combine the game goals, worlds, paths, movement in a few ways to create game ideas<br>b) If the early ideas resemble known games, iterate for more ideas. Use creativity techniques of choice such as TRIZ or Design by X (X = analogy, inversion, combination etc.). Discussion on Idea generation techniques is not in the scope of this thesis<br>c) Seek outside inspiration from sources indicated in figure (4.13)<br>d) Relate the ideas with the learning goals and the audience to make a list of suitable ideas | |
| SIGNIFICANCE: Multiple gameplay ideas allow selection of the best one from the lot | |

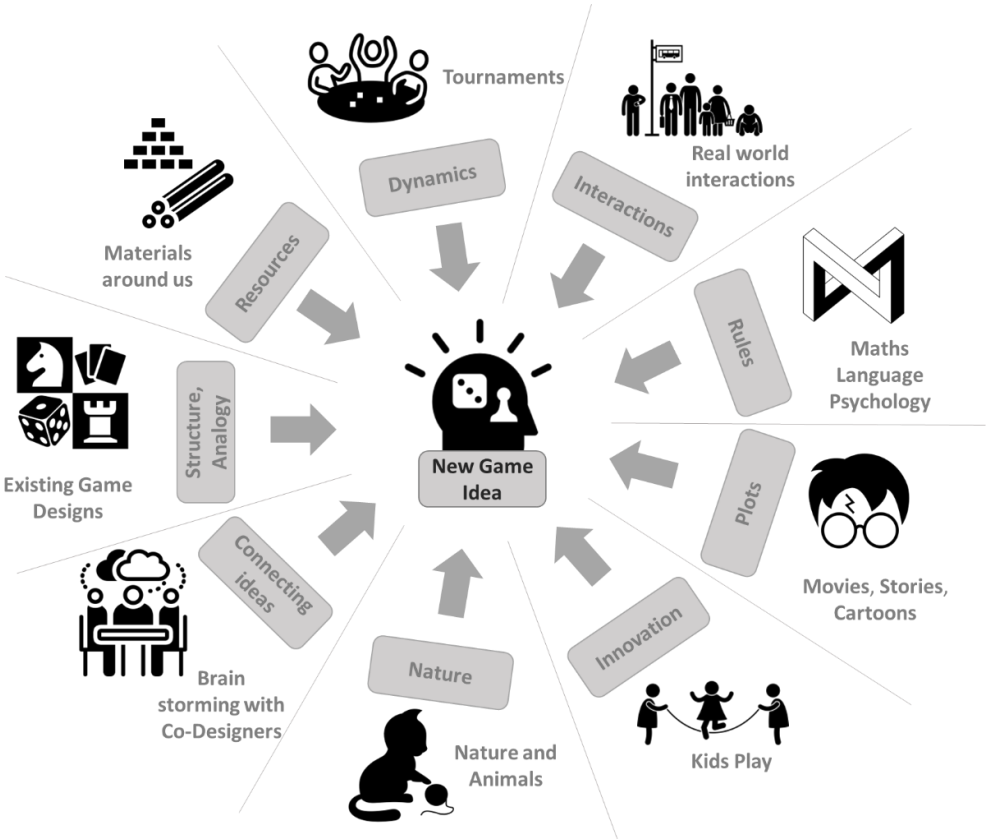


Figure 4.13 Game Idea Sources

## 4.3.4 Stage 4: Translation

After the divergence stage, with more than one rudimentary idea in the bank, the focus moves to translation. Translation is a critical stage contributing to endogenous design. The content elements extracted during the exploration stage are translated to game elements in this stage. These game elements need to fit into (one or more of) the gameplay ideas created in the divergence stage. If they do not fit then iteration is required in order to think of new gameplay ideas (gameworld, goals and movement). There are six steps in this stage (12 to 17).

| STEP 12 : REIMAGINE CONTENT ELEMENTS | STAGE: TRANSLATION |
|---|---|
| PURPOSE: Guides designers to reimagine the content elements as game elements | |
| GUIDANCE TO DESIGNER:<br>a) Observe the elements that stand out for translation. Reimagine how they can render themselves as resources or mechanics in the game<br>b) If not easily identifiable, use transformation techniques such as morphological charts to force ideas on translation | |
| SIGNIFICANCE: The re-imagination step is to trigger ideas for translation of content elements to resources and mechanics. | |

| STEP 13 : GENERATE RESOURCES | STAGE: TRANSLATION |
|---|---|
| PURPOSE: Guides designer to generate game resources from the content or otherwise. Resources can be translated from content and few others can be generated exogenously as well. | |
| GUIDANCE TO DESIGNER:<br>a) Translate objects and abstract entities to game resources. Physical objects are easy to identify and translate; however, abstract entities like 'rights' can also be used as resources in games. Apart from objects, the game resources can also be the spaces, land and so on<br>b) Think of additional resources that can work together with translated resources. Apart from the objects appearing in the topic, other objects can be added. For example, in the topic of 'rocks' metal, wood can be added if the game is about constructing a building<br>c) Think of resources that can map to the selected gameworlds, refine the gameworld if needed, or modify the suitability of resource. For example, if the gameworld is 'Mars' then oxygen can be a resource which is not naturally available but is carried from the earth, etc.<br>d) Bring the properties of objects from the content to the game. For example, rocks can be formed or broken. Imaginary capacities, properties can be also given to some resources. In the case of rocks, magnetic properties or sticking properties etc. can be added. However, adding such properties needs to be done carefully as a special power etc. and should not be counterproductive to learning goals<br>e) Classify resources that are mobile, immobile, exchangeable, combinable etc. The classification helps in the design of mechanics that can work with the resources<br>f) Decide which resources can move as tokens in the game (if any). Sometimes resources participate in the movement. One resource can modify other resource as well. In the game of 'heat', heat can be used to move metal on the path<br>g) Observe possible patterns and changes – e.g. arrangements, transitions in resources. These patterns also help in designing mechanics related to puzzles. Geometric shapes is an example<br>h) Artificial resources such as currency or lives can be added as necessary, but these may not become endogenous unless the topic itself is about monetary transactions or lives | |
| SIGNIFICANCE: Decisions on resources and their creative use are found to trigger better game ideas | |

| STEP 14 : GENERATE CORE MECHANICS | STAGE: TRANSLATION |
|---|---|
| PURPOSE: Guides designers to generate the core & satellite mechanics from the content or otherwise. | |
| GUIDANCE TO DESIGNER:<br>a) Translate the actions documented in the exploration stage to mechanics. E.g. Assemble - Atoms can be assembled into molecules<br>b) If resources are translated from content, mechanics can be identified as actions that can be performed on these resources (actions by actors, nature, system or other objects)<br>c) Try associating known mechanics such as collect, assemble, hide, trade, dispose, modify, enrich, run/jump, disappear, capture, etc. with identified resources. Designers can refer to available libraries of mechanics on the internet e.g. Jarvinen's library [2008]<br>d) Try associating verbs with the resources to generate realistic and fantasy actions. Different verbs can be associated with objects, spaces, and actors to generate new mechanics. For example, with the object 'Rock', collect, throw, break etc. are naturally associated. However, trying multiple verb associations can lead to novelty. For example, disappear, stick, grow, carve, and melt when associated with rocks lead to novelty. This strategy is similar to the VNA method of Kultima et al. [2008] in which verbs are used to generate mechanics<br>e) Check alignment of the mechanics with gameplay. Revise the gameplay if necessary | |
| SIGNIFICANCE: The system of mechanics largely defines the game design. The system of mechanics (the forward movement and opposition) enables the gameplay. | |

| STEP 15 : GENERATE OPPOSITION MECHANICS | STAGE: TRANSLATION |
|---|---|
| PURPOSE: Guides designers to create opposition mechanics. Opposition mechanics challenge and oppose the forward movement. | |
| GUIDANCE TO DESIGNER:<br>a) Identify opposites of the core mechanics – e.g. break vs build, acquire vs release, apply heat vs cold, get angry vs stay calm<br>b) Translate the contrasts e.g. heat vs cold etc. from the content to create opposition mechanics<br>c) Think beyond the obvious opposition mechanics. E.g. Fill versus void, in the mensuration game where players form shapes on the grid to claims areas, a novel opposition would be creation of 'voids' that can be placed to nullify claimed areas by opponents<br>d) In human behavior games, design pay-off matrices with penalties and incentives for each action. For example, in a road safety game, if safe driving is desirable, how does one oppose the safe driving? An incentive system is needed where the players have to make a choice between safe driving and unsafe driving (which needs incentives for unsafe driving as well). This may at times lead to ethical dilemmas, which need to be resolved<br>e) There can be satellite opposition mechanic also. In the same game of fundamental rights, a player's movement on the board is blocked by civil wars and other situations. A satellite opposition mechanics was geographical hurdles such as water scarcity | |
| SIGNIFICANCE: Sometimes, designers may create an opposition mechanic before the core mechanics. For example, in the game of fundamental rights, the designer may first think of situations where rights are compromised. | |

| STEP 16 : REVIEW LEARNING OBEJCTIVES | STAGE: TRANSLATION |
|---|---|
| PURPOSE: Due to the endogenous design process, there is no separate stage to integrate learning. The previous steps would have naturally embedded content in the game. This step is to review how much and how well the game elements have met the learning objectives. | |
| GUIDANCE TO DESIGNER:<br>a) Check which mechanics enable learning through actions/ practice/ consequences - esp. procedural knowledge<br>b) Check which resources (layouts, visuals, shapes, change of form etc.) enable learning through visualization – esp. conceptual knowledge<br>c) Check how gameworld elements/ cards enable learning - esp. factual knowledge<br>d) Identify opportunities for knowledge application – whether through calculations, strategy making, problem-solving, memory etc.<br>e) If the selected elements have covered the required learning goals, then designers can proceed to the next step. If the learning objectives are inadequately met, designers can go back to the exploration stage to identify new elements | |
| SIGNIFICANCE: This step allows designers to take stock and redesign as needed, to meet the learning objectives. | |

| STEP 17 : ASSOCIATE TRANSLATED ELEMENTS | STAGE: TRANSLATION |
|---|---|
| PURPOSE: Guides the designers to associate the translated elements with the gameplay ideas. | |
| GUIDANCE TO DESIGNER:<br>a) Associate resources, core mechanics, alternate mechanics and opposition mechanics to the gameplay ideas generated in the design-divergence stage<br>b) If the associations are weak, revise the gameplay, gameworld etc. by going back to the divergence stage<br>c) Make a list of viable and interesting combinations of these elements as potential game ideas<br>d) Use constraints - Restrict the range of one or more elements to generate novel combinations | |
| SIGNIFICANCE: The associations made in this step enable the convergence to final concept. | |

The endogenous design is enabled primarily by exploration and translation stages.

### 4.3.5 Stage 5: Core Design - Convergence

The design convergence stage is the counterpart to the design divergence stage. The multiple game ideas created with the translated elements are distilled. Interesting elements from multiple game ideas are merged into one idea for further development. There are four steps in this stage (18 to 21).

| STEP 18 : SHORTLIST AN IDEA | STAGE: DESIGN CONVERGENCE |
|---|---|
| PURPOSE: Guides the designers to shortlist an idea to pursue further. | |
| GUIDANCE TO DESIGNER:<br>a) Shortlist promising combinations from the associations in previous steps<br>b) Bounce off the ideas with other designers and potential players<br>c) Select one game idea using any suitable criteria. Alternatively use one of the following:<br>i. Meets the learning goals most<br>ii. Appears to be novel, fun to others<br>iii. Ease of further development<br>iv. If all are equal, use artificial constraints on one or more elements<br>d) Recombine elements from the several ideas if every idea has something good to offer | |
| SIGNIFICANCE: Shortlisting activity forces designers to let go of a few sub plots to make a compact game. Ideas that are left behind can be used in the next iteration to create more games. | |

| STEP 19 : DEFINE PLAYER INTERACTIONS | STAGE: DESIGN CONVERGENCE |
|---|---|
| PURPOSE: Guides the designers to design player interactions | |
| GUIDANCE TO DESIGNER:<br>a) Refer to the movement/path and decide elements (tokens/self/click etc.) that can be moved by the player, towards achieving the goal<br>b) Refine path/movement/goals if needed. The element to be moved can emerge from the content – e.g. electric charge<br>c) Decide which tool e.g., dice/ pawns/ tokens/cards/characters trigger the movement<br>d) Decide the choices that players have (or paths that players can take) at every move<br>e) Decide the nature of inter-player contest – whether it is cooperation or competition between two players, whether it is cooperation within the team and competition with the opposite team.<br>f) Decide game economy – how players create/acquire/hold/exchange/hide/buy/sell/dispose resources. The mechanics of trade can emerge from the content or can be superimposed. For example, trading of rocks is not a part of content in 'Rocks' topic, but it can be added to the game<br>g) Decide the player progression (path to mastery), splitting the game into levels (to manage difficulty). The progression can be derived from the course design in the textbooks.<br>h) Decide mechanisms for player feedback (scoring, reward and penalty system). The exact rules of scoring can be defined in the next stage | |
| SIGNIFICANCE: Defining player interactions gives a sense of completeness to the game. The designers also get clarity on how elements decided earlier are going to work together during play. | |

| STEP 20 : FORTIFY GAMENESS | STAGE: DESIGN CONVERGENCE |
|---|---|
| PURPOSE: The previous steps can provide interesting ingredients but it is not necessary that their integration will make a sound game. This step guides the designer to identify or introduce the defining characteristic of the game and fortify the same. | |
| GUIDANCE TO DESIGNER:<br>a) Identify the core aspect of the game in the shortlisted ideas. It can be contest, or the mechanic and goal combination or anything that brings sound 'gameness'<br>b) If required, seek unusual patterns, unexpected behaviors, unusual properties, constraints, unique situations, visuals patterns, and human habits from the content and create additional resources, mechanics.<br>c) Enhance, fortify the core contest/challenge which causes the motivation to play and beat<br>d) Introduce chance, random events, unique rules, guesswork. These elements are seen across games as elements that bring fun<br>e) Make the game path such that the players discover the novelty at different steps. Koster [2013] has said that fun is in identifying a pattern. When humans master certain patterns, new patterns are required for fun, hence the surprises.<br>f) According to Falstein [2005], fun is due to the learning opportunities that allow players to gain mastery of certain skills, solve puzzles, mysteries, and handle situations and so on. Make provisions for the same.<br>g) Go back to the translation stage if more elements are needed to make a good game | |
| SIGNIFICANCE: This step signifies that making a game is not about simply combining elements but finding that one contest, one rule, one challenge which makes players play the game | |

| STEP 21 : FINALIZE CONCEPT | STAGE: DESIGN CONVERGENCE |
|---|---|
| PURPOSE: Guides the designers to finalize the concept. Finalized concept can be altered in the next iteration | |
| GUIDANCE TO DESIGNER:<br>a) Give a name to the game<br>b) Draw final sketch of the layout<br>c) Describe game components – goal, gameworld, mechanics, resources, player interactions and learning afforded | |
| SIGNIFICANCE: Finalizing concept provides closure to core decisions. | |

If designers intend to create two to three concepts before elaborating, they can iterate back to the divergence stage to generate new elements and ideas. Designers can also choose to end the concept design process here and get reviews from co-designers or potential players on the concepts. If there is a need to elaborate, the designers go to next steps.

### 4.3.6 Stage 6: Elaboration

The elaboration stage is where the incomplete elements of game concept are completed. Decisions related to game rules and game dynamics etc. are taken. Designers may not use the elaboration stage if the expected outcome is only a high-level concept. There are six steps in the stage (22 to 27).

| STEP 22 : LIST MISSING ELEMENTS | STAGE: ELABORATION |
|---|---|
| PURPOSE: Guides the designers to make a list of incomplete or weak elements | |
| GUIDANCE TO DESIGNER:<br>a) Identify and list incomplete elements, as well as elements where detailing is yet to be done. Designers can refer to the Unified Framework [Agarwal and Athavale, 2017] for exhaustive list of elements. Alternatively, designers can refer to the ontology by Zagal et. al [2007].<br>b) Identify the weaker elements from the concept. Check if the design of gameworld, mechanics, resources etc. can be improved<br>c) Mentally play the game from start to finish for identifying what is missing | |
| SIGNIFICANCE: This step allows identification of any elements that have been overlooked. | |

| STEP 23 : DESIGN RULES | STAGE: ELABORATION |
|---|---|
| PURPOSE: Guides the designers to design various rules for playing the game | |
| GUIDANCE TO DESIGNER:<br>a) Rules can be made endogenous by translating rules in the reality. For example, rules that a 'fundamental right' is perpetual, a metal can be moved through a channel only when heated are derived from the content. Following rules need to be defined:<br>i. Rules for starting and ending the game<br>ii. Rules for movement, taking turns<br>iii. Conditional rules - conditional validity of actions<br>iv. Rules related to resources, their powers, power ups, exchange etc.<br>v. Define game ending rules, winning conditions<br>vi. Design trade-offs – what are the costs for acquiring possessions. These tradeoffs can be inspired by tradeoffs in real world<br>vii. Design a scoring system, how scores increase, decrease, rules for elimination<br>b) Designers also need to define who will enforce the rules – whether the game automatically regulates, whether it is voluntary or whether enforced by the umpires | |
| SIGNIFICANCE: Rules define the game. Everything else being same, just different rules can make games different. | |

| STEP 24 : DESIGN GAME DYNAMICS | STAGE: ELABORATION |
|---|---|
| PURPOSE: Guides the designers to design game dynamics. Game dynamics is the run time behavior generated by use of game mechanics. The designers indirectly design the dynamics through rules and randomness. | |
| GUIDANCE TO DESIGNER:<br>a) Dynamics can be made endogenous. For example, the eruption of volcano in rocks game can change dynamics.<br>b) Think of the pace of game and introduce elements to make it fast or slow (by tuning the steps, speed, powers etc.)<br>c) Plan events that get generated by chance (e.g. dice) so that uncertainty is retained<br>d) Design rules to keep the players who are racing ahead to equilibrium position. The equilibrium should be retained for a while so that players stay in competition for reasonable duration.<br>e) Introduce surprise outcomes on certain moves (esp. in digital games)<br>f) Introduce wild cards, special spaces | |
| SIGNIFICANCE: Provisions for dynamics are made at design time (this step). However, finalization of game-dynamics requires fine-tuning after playtesting. | |

| STEP 25 : ENHANCE LEARNING AND FUN | STAGE: ELABORATION |
|---|---|
| PURPOSE: Guides the designers to integrate instructional strategies for learning as well as aesthetics for fun | |
| GUIDANCE TO DESIGNER:<br>a) Design a mechanism for ensuring that authentic learning elements are clearly known. This is especially critical when the game has fantasy elements. For example if a designer has created an action 'disappear' for a rock in geography, then it must be clearly called out as action that is not in real world. This can be done in many ways – for example, the real and fantasy actions can result in different scores e.g. blue coins for 'disappear', whereas green coins for 'build' (to separate authentic actions)<br>b) Add feedback elements that support learning – e.g. messages/cards/scores/summary. Such explicit additions are necessary when some aspect of learning is to be emphasized<br>c) Design elements that enhance fun – aesthetics/ graphics, design of tokens, cards, background and characters that suit the gameworld as well as the educational topic. Many designers in digital game design begin with characters and background. However, for endogenous design it is better decided later so that it does not become a limitation<br>d) Some content elements can be introduced such that they are revealed after playing different parts of the game or by playing the game again etc. | |
| SIGNIFICANCE: A review by an academician at this stage can be useful to find out whether the learning content and transfer needs any corrections. Feedback, progression and mastery are essential instructional strategies that need to be consider in design of learning media | |

| STEP 26 : REFINE THE DESIGN | STAGE: ELABORATION |
|---|---|
| PURPOSE: Guides the designers to check if all the design details are in harmony with each other refine and reduce unnecessary elements | |
| GUIDANCE TO DESIGNER:<br>a) Refine weaker elements. Rework on them<br>b) Check if elements are coherent with each other. Address coherence between movement, mechanics, rules, player interactions. If the coherence is lacking go back to convergence stage<br>c) Focus, reduce unnecessary elements, make the game compact | |
| SIGNIFICANCE: This is an opportunity to relook at the details before closing the design concept | |

| STEP 27 : CREATE A PROTOTYPE | STAGE: ELABORATION |
|---|---|
| PURPOSE: Guides the designers to build a low fidelity prototype | |
| GUIDANCE TO DESIGNER:<br>a) Create prototype of the board, cards and tokens using paper, cardboard, cards, colors etc. OR Create a screen mock-up for digital prototype<br>b) If the learning modules follow pattern e.g. chemical reactions, then design a prototype to exemplify one such case<br>c) Attempt a low fidelity prototype initially. Focus on core elements, all the details need not be added to early prototype. | |
| SIGNIFICANCE: Prototype creation is an optional but useful step. Many game design books advise quick prototyping and play testing. However, our framework focuses more on concept development | |

In the next stage, the game concept and the prototype can be subjected to verification.

### 4.3.7 Stage 7: Verification

In the verification stage, designers are guided to verify the concept for completeness, meeting the learning objectives and the potential engagement. This stage has four steps (28-31).

| STEP 28 : VERIFY COMPLETENESS | STAGE: VERIFICATION |
|---|---|
| PURPOSE: Guides the designers to verify completeness of the game concept | |
| GUIDANCE TO DESIGNER:<br>a) Use the game description template (provided as part of framework kit) to check if all components of the concept are complete. The checklist includes the name, medium, number of players, game goal, learning goal, gameworld, layout, path, movement, narrative, mechanics, opposition mechanics, resources, player interactions, and rules<br>b) Self evaluate the quality of design of each element<br>c) Mentally play the game to identify lack of coherence, completeness<br>d) Get reviews done from other designers or representative players<br>e) If the detailed design needs more work, designers can go back to the elaboration stage | |
| SIGNIFICANCE: Verification of completeness reveal the gaps that need to be plugged | |

| STEP 29 : VERIFY PLAYER ENGAGEMENT | STAGE: VERIFICATION |
|---|---|
| PURPOSE: Guides the designers to verify potential player engagement of the game concept. At the concept stage, player engagement is mostly a subjective assessment using a sample. | |
| GUIDANCE TO DESIGNER:<br>a) If only a concept is created then potential engagement can be assessed through expert opinions<br>b) If a prototype is created then the player engagement can be verified through play testing. Representatives from the intended audience can be invited to play<br>c) Engagement can be verified through observation as well as by using established player engagement questionnaires [Brockmeyer et al., 2009]<br>d) If the engagement is inadequate then revisit the translation and design stages | |
| SIGNIFICANCE: Assessing the potential player engagement is essential to understand what is working well and what is not | |

| STEP 30 : EVALUATE LEARNING OBJECTIVES AND COVERAGE | STAGE: VERIFICATION |
|---|---|
| PURPOSE: Guides the designers to verify the learning objectives and coverage | |
| GUIDANCE TO DESIGNER:<br>a) Check whether the learning objectives in the brief are met (for the selected chunks in step 2).<br>b) A subject matter expert can be requested to verify if the objectives are sufficiently met<br>c) Find out if any part of the game contradicts intended learning outcomes. Such contradictions need to be resolved<br>d) Identify how many chunks of the content are included in the game. Decide if additional chunks can be added to the same game with new levels<br>e) If the coverage and objectives are inadequately met, iterate from the exploration stage | |
| SIGNIFICANCE: A game should not be too trivial in its learning content nor should it be too saturated. This balance can be verified based on learner feedback. | |

| STEP 31 : CHECK ENDOGENOUSNESS AND FINALIZE | STAGE: VERIFICATION |
|---|---|
| PURPOSE: Guides the designers to complete any changes required after verification. | |
| GUIDANCE TO DESIGNER:<br>a) Use the endogenous design rubric (which is part of the framework kit) to verify the endogenous nature of the concept<br>b) Rework on additional elements for endogenousness if necessary<br>c) Atleast one iteration through all stages is suggested before finalizing<br>d) If the design is adequate, make required corrections and finalize the concept | |
| SIGNIFICANCE: Endogenous design leads to both engagement and learning. Hence verifying whether the design has achieved the same is essential. | |

At the end of verification stage, either a new iteration begins for additional ideas or the game design activity is closed.

### 4.3.8 Stage 8: Reflection

Schon [2017] suggests that design is a reflective practice. Reflection on the design activity provides useful learning that designers carry to the future. After using the framework, designers can think of improvisations and newer strategies. Designers can share the feedback with the researcher to improvise the framework and use the improvisations for bettering their own designs in next iterations.

| STEP 32 : REFLECT | STAGE: VERIFICATION |
|---|---|
| PURPOSE: Guides the designers to reflect on their work and improvise. | |
| GUIDANCE TO DESIGNER:<br>a) Reflect on the nuances of the topic and what it offered for game creation<br>b) Reflect on the endogenous nature of the concept<br>c) Reflect on how the strategies helped<br>d) The designers can contact the researchers for providing feedback and contribute to the repository of strategies | |
| SIGNIFICANCE: Reflection is an important tool that designers can use to make future designs better | |

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**Summary of Chapter**: The Endogen framework and the constituent strategies are presented in this chapter. Validation of the framework will inform us about the practical utility and bring out the strong points as well as the shortcomings, if any. In the next chapter, we formally validate our framework and strategies using various methods.

# Chapter 5 **Validation and Potential Adoption**

"A design theory or model should not only meet the usual criteria of a descriptive science (e.g. truth, completeness, level of detail) but also the criteria of usefulness and timeliness" [Weber, 2014]. The practical utility of research is also a tenet of DBR. In this chapter, we discuss the validation of the framework with focus on utility. Further, we discuss and address the issues in the potential adoption of the framework.

## 5.1 Validation of Framework

Validation was carried out at every stage of research, beginning with the validation of the objectives. The objectives were validated for their clarity, scope, and their value in addressing a knowledge gap. Next is the validation of research methods. Since we selected established methods, their additional validation was not necessary. However, we validated the specific adaptations and extensions of these methods through a pilot study. The codes and inferences were validated using inter coder ratings.

Finally, during the process of synthesis, a formative validation of the framework was carried out. User feedback was iteratively taken to improve the framework as discussed in the earlier chapter. After the framework was fully synthesized, a summative validation needs to be carried out. In this chapter, we discuss the summative validation. In order to carry out systematic validation, the purpose, the criteria and the method need to be articulated. These aspects are discussed further.

### 5.1.1 Purpose

Lindemann [2014] informs that the objective of validation is to show that the purpose of the framework will be fulfilled. This utilitarian view is consistent with the Design Based Research (DBR) approach. In DBR, the research results are primarily validated through the significance of their use, providing consequential evidence or validity [Barab et al., 2009, Messick, 1994]. The utility of the Endogen framework is in enabling designers in creating endogenous design of educational games.

However, utility is not a one-dimensional measure. The behaviour of the framework provides multiple dimensions for assessment of the utility [Gero and Kannengiesser, 2014]. The expected behavior of the Endogen framework, indicating four dimensions of utility, is described in earlier section {4.2.2}. Measurement criteria indicated in figure (5.1), further operationalize the four dimensions.

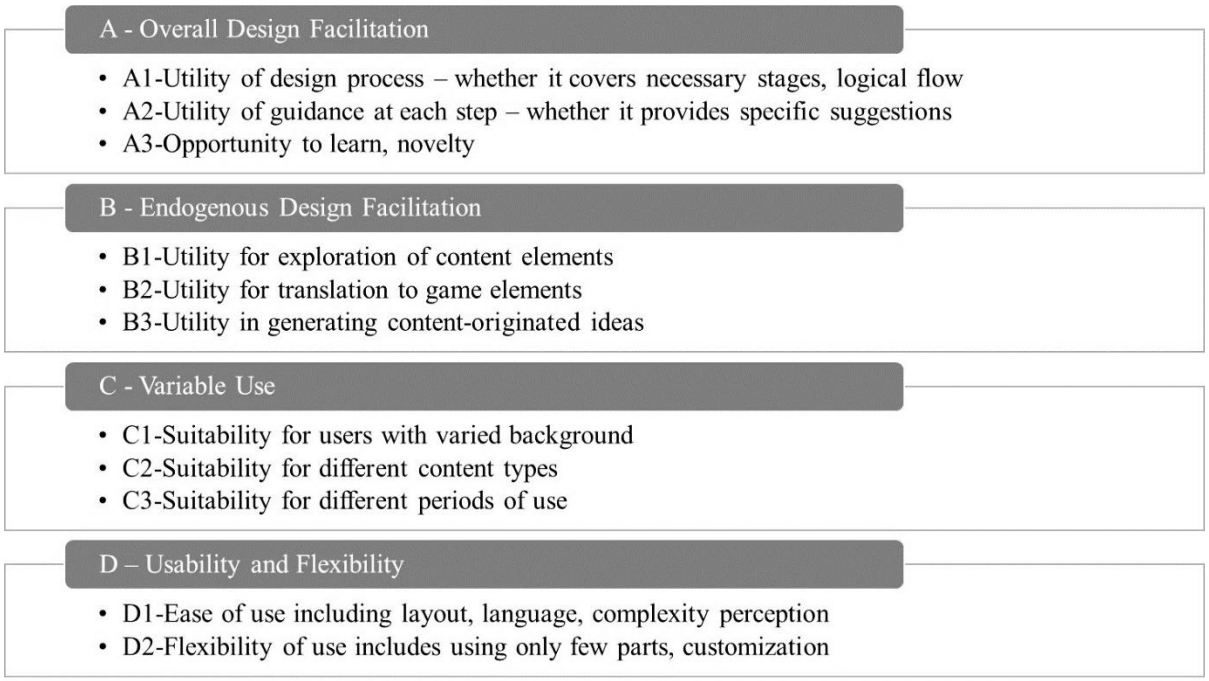



Figure 5.1 Dimensions of Validation

Each dimension helped in validating a certain aspect of the utility. The first dimension A is overall design facilitation. It suggests that the framework should guide the designers through a step-by-step process from start to finish. This is broken into criteria A1/A2/A3.

The criteria A1 suggest that the framework should cover necessary stages, provide logical flow, and lead to specific outcomes. A2 suggests that the guidance provided at each step should be useful and there should not be unnecessary steps or fewer than necessary steps. In short, it should avoid the problems of over definition and under definition. A3 suggests that the framework should provide opportunity for the designer to learn new way of doing things, atleast during initial use.

The second dimension B is Endogenous design facilitation. While dimension A focuses on the completeness of process, B is specific to enabling endogenous design. It again has three criteria B1/B2/B3. Endogenous design can be created when the exploration and translation of content elements is achieved well. B1 suggests that framework should provide support for exploration and B2 suggests for translation. B3 suggests that the framework should help in generation of endogenous game ideas.

The third dimension C is for validating the suitability for use of the framework in varied conditions. Criteria C1 suggest that framework should be suitable for use by designers with varying backgrounds. Users having game design experience as well as students of game design, education technologists should be able to use the framework. C2 suggests that framework should be suitable for designing games for topics having factual, conceptual and procedural content. C3 suggests that the framework should be suitable for using in a single session as well as over a longer duration.

The fourth dimension D focuses on the usability and flexibility that framework should exhibit. Criteria D1 suggest that framework should be easy to use. The language, layout, and detail should not be complex. D2 suggests that framework should be flexible in allowing users to use it in entirety or in parts as well as in different sequence.

### 5.1.2 Methods

The methods describe how the criteria defined earlier will be validated. Ranjan et al. [2014] propose two ways to validate design knowledge: first, using empirical data, and second, through verifying logical consistency with previously validated theories or models. There are several ways of empirical validation used in engineering design research, including comparative studies, focus groups, interviews, case studies, simulations [Barth et. al, 2011].

However, validating design research has many challenges – the most significant being the difficulty in finding a statistically large number of subjects. Another challenge is the amount of effort and data involved in analysing observation studies [Chakrabarti and Blessing, 2016]. Therefore, qualitative methods such as case studies are widely used to validate design research. For example, Hall [2014] validated his Serious Games Framework using case studies. Cavallucci [2014] used industrial case studies to validate his framework.

We used a multimethod approach to validate the criteria defined in previous section. The multi method approach provides triangulation and brings internal validity to the results [Khambete et al. 2015]. Each method either covers up missing measurements of other method, or provides double check. The three methods that we chose are:

a) Comparative studies
b) Design workshop and focus group interviews
c) Longitudinal design assignments

Each of the selected methods and their application in our validation studies is described further.

**Comparative Studies**

Comparative studies focus on the incremental/differential utility of the Endogen framework as compared to the existing knowledge. Since there was no other framework available on endogenous design, we created a new process framework as baseline for comparison. The new process framework guides the designer in overall design process with broad stages, but is devoid of specific strategies for endogenous design. It was named 'Ten-Step' framework and is shown in figure (5.2).

To conduct the comparative studies, two groups were formed, a control group and an experiment group. Endogen framework was given to experiment group and Ten-Step framework to the control group. Each group had five participants and duration of each session was three hours. We did not select common participants between the groups but adequate care was taken to match the backgrounds of participants in both the sessions in terms of design experience, age, gender etc. Participants in both groups were given advance preparation material on game design and a brief on endogenous design. None of the participants was informed which group they belonged to, nor were they informed about the framework. At the end of the session, participants would provide ratings for the framework they used.

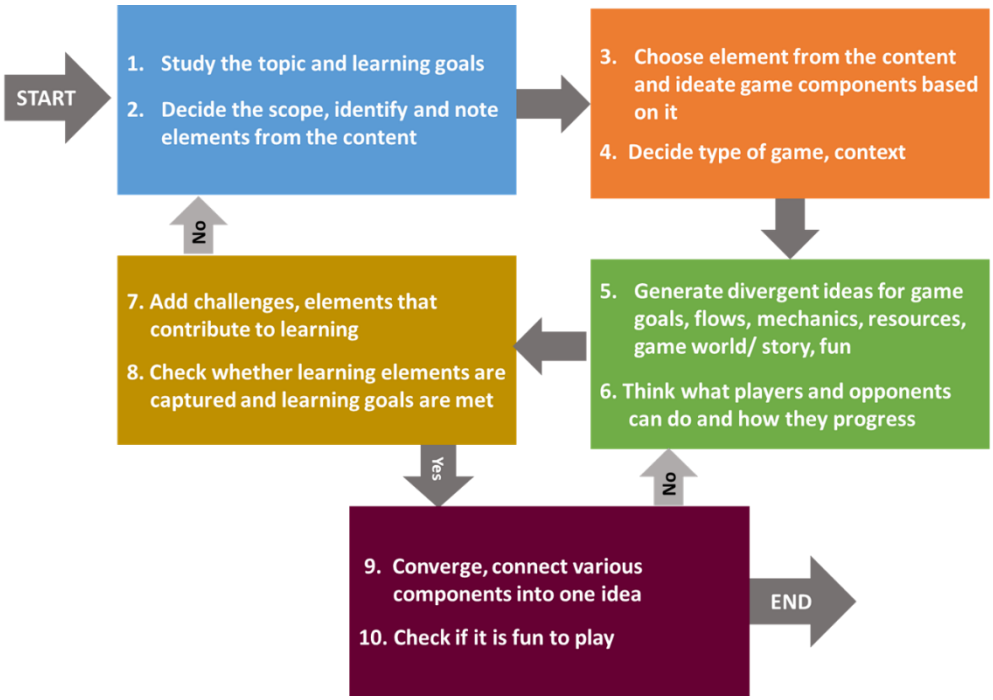



Figure 5.2 Ten-Step Framework

In both sessions, exactly the same educational topics were administered. They were Administration of Swaraj (History), Motion and Force (Physics), Equations (Maths), Bio-Diversity (Science) and Conflict Resolution (Self-Management). The topic distribution was similar to the main studies, based on the Anderson Krathwohl classification [Anderson et al., 2001] of factual, procedural and conceptual content. The distribution of topics created a variable use condition C2.

A questionnaire with rating scale was developed to collect feedback on the frameworks. It is attached in appendix {B1}. An independent reviewer was invited to rate the same questions in both sessions, based on his observations. Independent reviewer was also provided with rubric to measure endogenousness {as in Section 2.8}. We checked the internal consistency of responses by comparing the ratings given by participants with those given by the reviewer.

**Design Workshop and Focus Group Study**

The design workshop and focus group studies were conducted by inviting participants having education technology background to get in depth feedback on the utility of framework. Education technologists brought unique knowledge of educational techniques, tools, as well as methods of learning for a variety of content and audiences. They also bring knowledge about frameworks for instructional design and are well equipped overall, to evaluate the utility of our framework. Education technologists are also the intended user groups of our framework.

We recruited PhD scholars from the Educational Technology department at reputed institution as participants. Participants are given advance background on game design. The duration of design workshop was four hours. Focus group approach was chosen to encourage discussion among participants after they complete the design. Interviews were conducted at the end of the workshop using a questionnaire, prepared by referring to Krueger et al. [2002]. It is attached in Appendix {B2}. The topics for the four participants were selected from earlier topics in the main studies and comparative validation. This study provided deep insights on most criteria, especially 'variable use' dimension C1 and C2.

**Longitudinal Studies**

Longitudinal studies provide data about the utility of the framework over a period. From the longitudinal studies, we sought answers to the questions about sustained utility and suitability of framework as ongoing reference (criteria C3). In the other two methods, which use single session design assignment, the participants may overlook certain details. However, in the longitudinal study, high fidelity feedback was expected. This method would also provide insights on most validation criteria apart from C3.

An essential element for successful longitudinal studies is the commitment of participants. We identified five participants who agreed to design game concepts over a period of a week. Few participants had participated in the comparative validation studies earlier. Three participants were given same topics from the comparative study and two were given different topics. At the end of the week, participants turned in their ideas and we conducted semi-structured interviews with them. The questionnaire for the same is attached in Appendix {B3}.

The overall validation approach is thus a combination of the three methods. This multi-method approach allows testing various conditions such as multiple topics, participants, durations and evaluation techniques to make our claims stronger. The summary of validation design is indicated in table (5.1). Using this design, the studies were conducted over a period of two months.

Table 5.1 Validation Design

| | **Comparative Studies** | **Focus Group** | **Longitudinal Studies** |
|---|---|---|---|
| **Focus** | Comparative Utility | Expert opinion on Utility | Utility over time |
| **Treatment** | Endogen and Ten-Step framework in control and experiment groups | Endogen framework | Endogen framework |
| **Duration** | 3 Hour session (2 sessions) | 4 Hour session | 8 Days (offline) |
| **Participants** | Total 10, 5 in each session, including designers and non-designers | 4, Education technology scholars | 4, including designers and non-designers |
| **Data Collection** | Observations and questionnaire | Observations and Focus group Interviews | Self report and interview |
| **Analysis** | Qualitative and quantitative | Qualitative | Qualitative |
| **Evaluator** | Participant (self) and independent reviewer | Participant (self) and group discussion | Self report and researcher |
| **Topics** | New topics | Mix of topics from main studies and new | Mix of topics from main studies and new |

The results from the three validation studies are discussed further.

### 5.1.3 Results

**Comparative Studies**

We compared the participant responses in both the sessions: one that used Endogen Framework and the other that did not. Participants rated the answers to questionnaire on a scale of 1 to 5 on every parameter. Similarly, the independent reviewer rated the same set of questions by observing participants and their work. The ratings of the reviewer and the individual were combined using a weighted average.

With five samples in each group, there were limitations on conducting statistical tests. We tried the Wilcoxon rank test to compare data between Endogen and Ten-Step groups. Figure (5.3) shows the box plots. In the figure, the scale is one to five, where one indicates a high rating and five indicates a low rating. Significant statistical difference ($p < 0.05$) was seen only on A2 (detailed guidance in each step) and it was in favor of Endogen framework. This difference was obvious because the Ten-Step method was devoid of any step-level guidance.

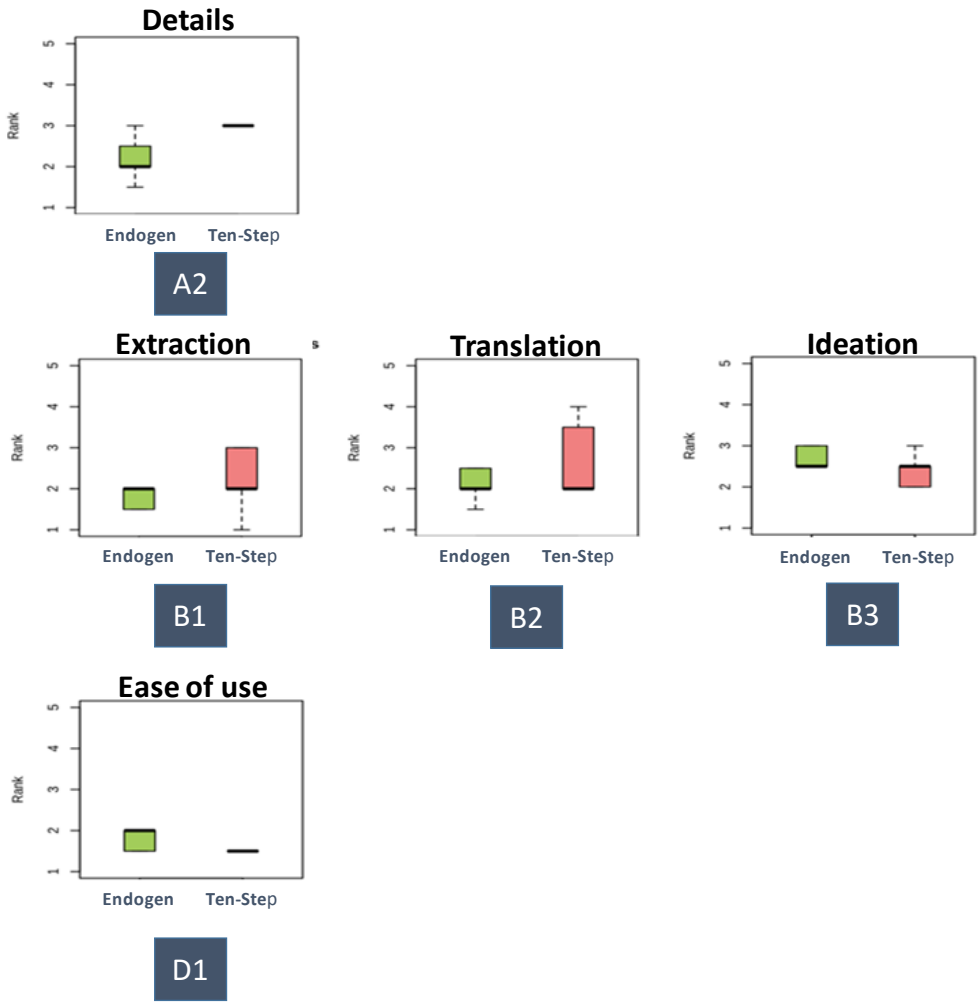



Figure 5.3 Box Plot for Comparative Validation

Due to the smaller sample size, we relied more on qualitative interpretation. The Endogen framework fared better than the Ten-Step on the 'usefulness of guidance at each step' (A2), however, it fared at par on the 'design process' (A1). This is not surprising because both the frameworks had a high-level process but only Endogen had detailed steps and strategies. It could not be verified whether the additional guidance helped in better completion rate of design. In both the sessions, three out of five participants could complete their concepts. A3-the 'opportunity to learn', was rated same in both frameworks. The Ten-Step framework, even without details had a process to be learnt. However, the opportunity was much higher in Endogen framework due to specific strategies.

The Endogen framework fared better on 'exploration and translation' (B1/B2) but Ten-Step fared better on 'idea generation' (B3). The result on B3 was unexpected but it can be attributed to the fact that Ten-Step framework had less structure. On B1 and B2, the Endogen framework fared much better because it had specific strategies to carry out the design activities.

In the ‘variable use’ dimension (C), the Endogen framework fared better on ‘suitability for users with different background’ because, participants from non-design background could use the detailed guidance, which was not available in Ten-Step. Criteria C2 – suitability for different content could also be validated because there was no difference in the outcomes based on topics. Criteria C3 were not tested in this study. On the ‘Usability and Flexibility’ (D), the Ten-Step framework fared better on ‘ease of use’ and ‘flexibility’ because it was open-ended with significantly less structure.

In summary, the Endogen framework fared better on guidance at each step, facilitating endogenous design and suitability for users having no game design background. However, it fared average on idea generation and ease of use.

**Design Workshop and Focus Group**

Data collected from the focus group interviews was recorded, transcripted and analyzed. The figure (5.4) shows participants in action. Two participants from the four recruited for this study, completed the game concept and the other two only partly, but all four participated in the discussion.

Figure 5.4 Participants in Focus Group

Between the three methods, focus group interviews provided deeper insights, especially on improvements. On the 'overall design facilitation' dimension (A), the participants suggested a change in the arrangement of stages. It was to make ideation a parallel activity to all the stages instead of keeping that at only two places. The 'utility of steps' (A2) was reported as 'very high' for the exploration stage (on the scale of low-average-high-very high). The 'opportunity to learn' (A3) was mentioned as 'high' because the participants found a new way to look at the content.

On the 'endogenous design facilitation' (B), the exploration stage (B1) was found most useful feature as in previous method. Some cards, e.g. step no 7, were found extremely useful. It was again reported that framework did not help much in idea generation (B3).

The 'variable use' dimension (C) was best validated through this group as the participants belonged to a different background and not game design. With respect to C1, it was observed that the participants could do the exploration very well. Participants could systematically explore the content using the framework, but they struggled with idea generation. This is so because, unlike designers, they were not formally trained in idea generation techniques. This informs us that the framework needs adaptation for different users.

The participants also reported that framework was suitable for different types of content (C2). This could also be independently verified as we had assigned topics belonging to different content type (factual/ conceptual/ procedural) in each design study. We however observed that endogenous design was difficult for topics such as 'fundamental rights' and 'conflict management'. It appears that the difficulty offered by each type of content is different and further analysis is required to confirm the same.

On the 'Usability and Flexibility' (D), it was found that there is scope to improve ease of use, especially simplifying the terminology and language. Participants also observed that the framework was overwhelming with number of steps and a graded or layered approach be considered.

In summary, focus group study confirms the utility of the framework for users with different background. It also reinforces that exploration strategies are very useful.

**Longitudinal Studies**

In the two methods discussed previously, feedback was based on a single design session. In a single session, participants may overlook certain details but longitudinal study can cover the same. Hence, we conducted longitudinal studies with five participants over a period of a week.

The longitudinal studies were conducted after the comparative and focus group studies as we recruited three participants who also participated in comparative studies and two were recruited fresh. At the end of the duration of design, four participants turned in their ideas and we conducted interviews with them. Based on the feedback, it was found that participants typically spent 30 minutes to two hours in a day, and used it for four to six days during the week. The framework was always kept available for reference. Within the framework, the board was referred to first and cards for respective steps were checked as needed.

Within the 'overall design facilitation' dimension, criteria A1, participants appreciated the organized approach facilitated by the framework. One participant said she followed the process one hundred percent as per the framework. However, two of them suggested that the ideation happened in parallel rather than sequentially. This feedback is similar to that received in focus group. There was a mixed reaction to the level of detail (A2). Two participants suggested that the details are just right, the third saying details are slightly more than necessary and fourth saying some more details on how to design 'movement' was needed. The 'opportunity to learn' (A3) was enhanced due to the available duration and participants expressed that they mastered the framework in a week.

On the 'endogenous design facilitation' (B), there was no new finding. The exploration and translation phases were used the most, reconfirming it as the core utility of the framework. Participants reported that some cards were very useful – especially step 7 and 14. The feedback indicates more focus on exploration and translation stages but lesser on elaboration and verification, despite having time at disposal. It appears that once the designer has the building blocks, handholding is not required in elaboration and verification. In any case, endogenous design is enabled predominantly by the exploration, core design and translation stage. Not using elaboration stage does not affect endogenous design.

The longitudinal study confirms suitability for longer use (C3). Participants informed that they referred the framework every time they worked on the assignment in the weeklong period.

Longer use enabled them to generate more than one concept as well as refine the concepts. On the ‘Usability and Flexibility’ dimension (D), the participants suggested that examples could have helped. We expected that couple of participants may extend or modify the framework but it was not observed.

In summary, the longitudinal studies indicate that framework has enough richness to provide value over a period of time and for repeat use.

### 5.1.4 Theoretical Comparison

Ranjan et al. [2014] have suggested a theoretical comparison with already validated frameworks as a way of validation for new frameworks. The theoretical validation is done using the tests of convergence and divergence. Convergence implies how related the proposed framework is to the existing frameworks, whereas divergence test is about how different it is. The proposed framework needs to be convergent enough to justify common foundation but divergent enough to justify the novelty and necessity of a new framework.

The existing serious game design frameworks largely focus on integrating the learning mechanics such as scaffolding, feedback, progression etc., with the game mechanics. These frameworks do not deal with translation of educational content into game elements. For endogenous design, the essence is the restructuring of content into game elements. Few frameworks that we analysed in chapter 2 define a high-level process for integrating content but do not indicate specific strategies. Endogen framework therefore offers a differentiating value in providing specific strategies for content to game translation.

The approach for the synthesis of our framework is situated in the formal approaches proposed in the field of design research as indicated in section {4.1}. We have used the functional, behavioural and structural foundations of the existing design frameworks to propose the Endogen framework. Thus, our framework satisfies the criteria of convergence.

### 5.1.5 Summary of Findings

Cumulative findings from the studies indicate that the purpose of the framework in providing guidance on endogenous design has been adequately met. Users reported that strategies were extremely useful for the extraction of content elements and translation to game elements. One participant expressed that "endogenous design came naturally while using the framework". The framework provided differentiating value in the form of endogenous design strategies as compared to reference framework that was used. Every participant reported that she would use the framework in future for her educational game design needs.

As part of the 'Overall Design Facilitation', users appreciated the organized approach, completeness of the process, and the strategies furnished at each step. One participant reported that the framework gave her a systematic approach to design artefacts beyond games. The elaboration and verification stages were less frequently used, probably because there was no directive on the level of detail to be produced. Few participants requested that the stages in the framework be parallel rather than sequential. This can be taken up as extension of current research in future.

Results indicate that the framework was suitable for users having background in game design, education technology and other fields. Novices in game design requested simplification of terminology. Participants who did not have design background, requested inclusion of ideation techniques. Ideation strategies have not been included in present versions, as these are available elsewhere. The suitability for designing games with factual, procedural, and conceptual content was confirmed based on the outcomes for varied topics. One participant requested that strategies for designing games with multiple technologies such as Augmented Reality, be considered in future. Framework was suitable for variable periods of use as well. Designers could create outline concepts in a single three-hour session and refined concepts in a week.

Based on the feedback, the 'ease of use' needed betterment. This could possibly be done by providing multiple examples as was requested. Some participants suggested that the level of details were initially overwhelming. A graded presentation of the details can be considered in a future work. The 'flexibility' of the framework was appreciated as users could exercise the choice of picking up any step in any stage or the entire process. The guided flow in the framework is akin to a guided path in a zoo where the visitors have a choice to follow the path or directly tour the exhibits of interest.

## 5.2 Potential Adoption of Framework

In this section, first we demonstrate use of the framework with a walkthrough of game design activity. The potential usage and issues in adoption of the framework are discussed next. Finally, we enlist ideas for possible extensions of the framework in future.

### 5.2.1 Packaging

The endogenous design kit consists of several items supporting the framework. The kit is designed for tabletop use and the designers/facilitators of the session would require appropriate printouts for use. The framework and supporting elements can be used by designers singly or in a team environment.

The kit consists of the following items:

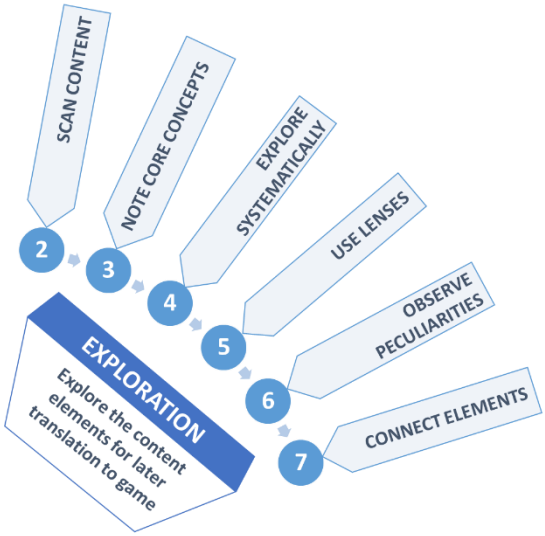
1. A readme file provides information on how to unpack the components and print
2. An introduction to the framework with information on how to begin using the framework
3. The Endogen board (radial layout)
4. The strategy cards
5. Example walkthrough (which is also presented in this chapter)
6. Game concept description template. Appendix {A4} shows the version used in studies, which was modified later. This also acts as a completion checklist.
7. Evaluation Rubrics as in Appendix {A7}
8. Orientation to game design (for those who are uninitiated in game design)
9. Feedback form (which designers can fill at the end of session and send back to researcher)

The Endogen board and strategies (points 3 and 4) have been detailed earlier in chapter {4}. Next, we present a design walkthrough of the framework by taking an example (point 5).

### 5.2.2 Design Walkthrough with an Example

In this section, we conduct a step-by-step walkthrough of the selected strategies from the framework to design a game for the topic ‘Rocks’ in geography. This chapter in the middle school textbook provides information about different types of rocks, their properties, their sources, formation and uses. This topic was assigned to couple of participants in our studies. The design brief urged participants to make the topic exciting to students in the age group of 11 to 14 through creating a game with endogenous design. We pick up one example to provide commentary on how the strategies were used to create the concept of the game on ‘Rocks’.

**Step-by-Step Walkthrough**




1. In step (01), the reference material is collected from the internet.
2. In step 02, the chapter is read. The content focuses on definition of rocks, its types and rock formation cycle. These are the core concepts (step 03). Since the chapter is small, chunking is not done.
3. In step 04, systematic exploration is done. Objects, Environment, Actors and Actions are identified.

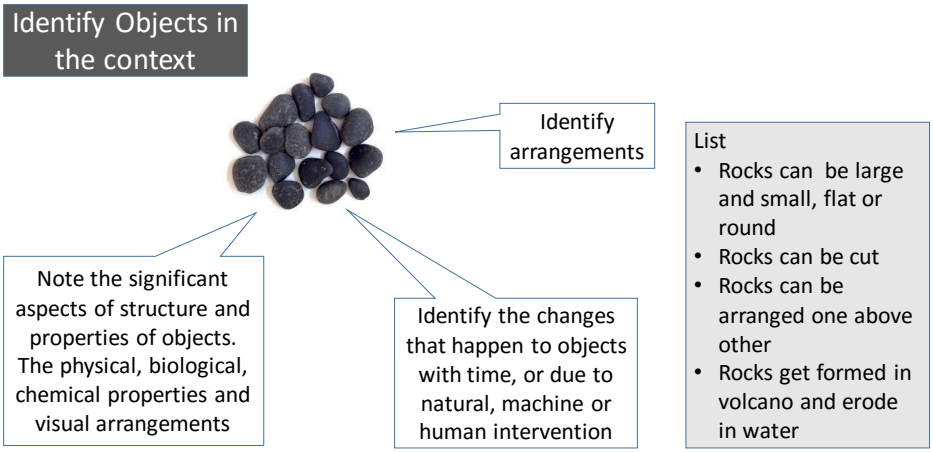



Figure 5.5 Game of Rocks - Systematic Exploration 1

It is noted that rocks have different shapes, with different properties such as brittleness, layers, and different ways of formation as shown in figure (5.5). Rocks can be found spread on the ground, or arranged on one another. Next, the environments of rock formation and rock usage are observed to make a list of elements as in figure (5.6). Further, the actors and the actions with the objects and their motives are identified as in figure (5.7). Actors can change the state of the object through their actions. They are mostly humans but can be systems, nature etc., as well. Humans use rocks for building houses, castles, roads, or as precious stones etc. Since significant elements could be identified, the strategy of the lenses (step 05) is not used. The actors can also be nature, such as seasonal changes that affect the rock formation cycle. In case non-human actors are chosen, the players will need to play as the personified character of say sun or water etc.

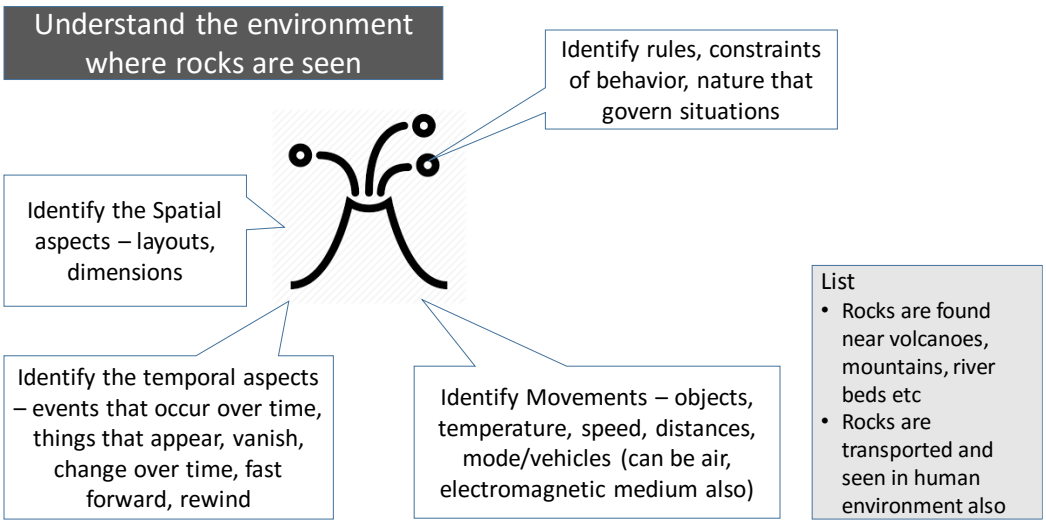



Figure 5.6 Game of Rocks - Systematic Exploration 2

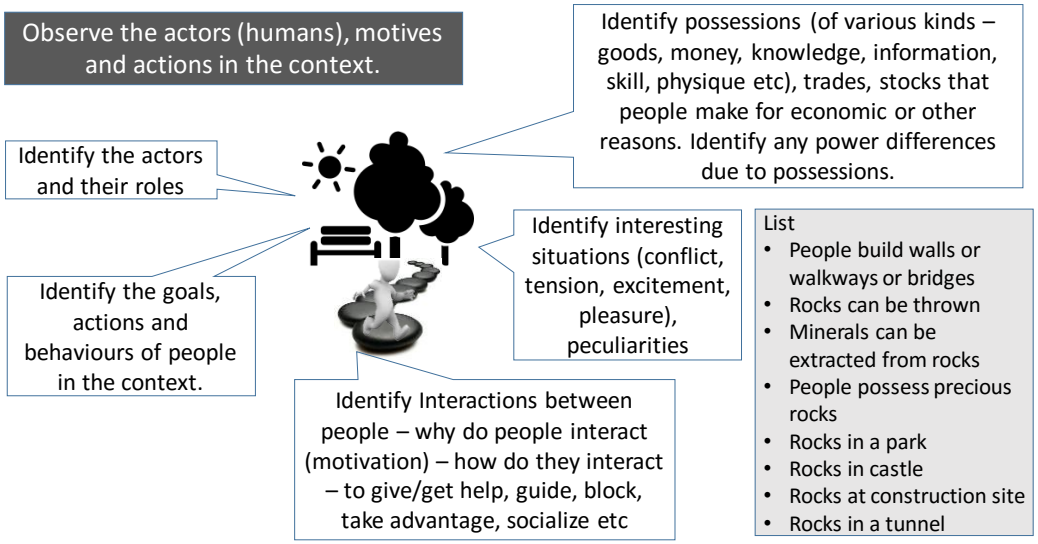
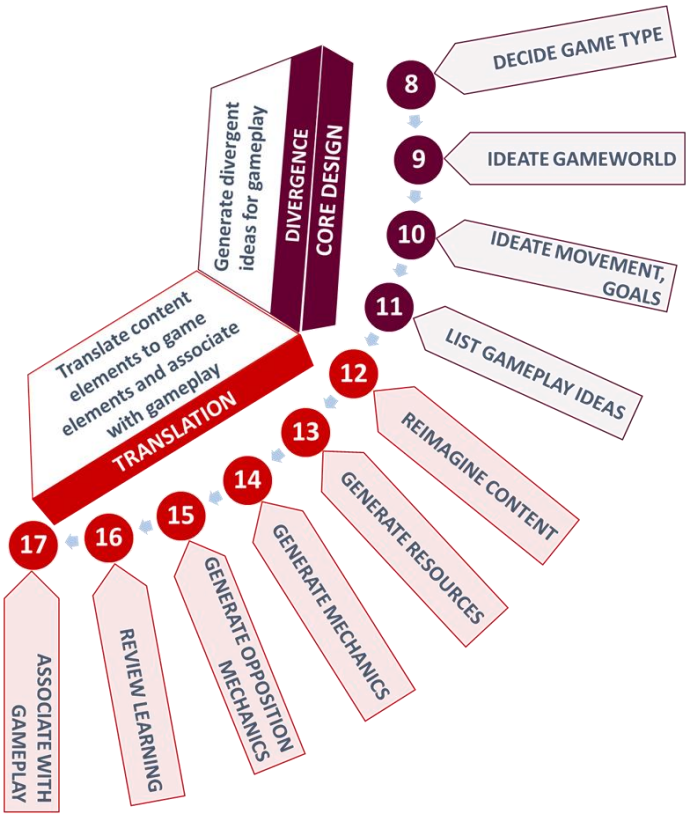



Figure 5.7 Game of Rocks - Systematic Exploration 3

4. In step 06, peculiarities are identified e.g., sedimentary rocks can have fossils. Igneous rocks can be well formed like granite or ill formed like basalt and hence have different uses.
5. In step 07, connections are identified. For example, the actors can be construction managers who are building houses, kings who wish to build castles, gem stone dealers etc. They need rocks of certain kind. They act on rocks – e.g. process them, transport them and then arrange them, stick them, etc.




6. In step 08, the medium of the game is decided. Since handling a variety of rocks and their usage in a physical game will be challenging, a digital medium is chosen.
7. In step 09, a fantasy world of castles is chosen inspired from the popular digital game ‘Clash of Clans’. Therefore, the goals in step 10 are to build castles and destroy the opponent’s castle. In step 11, only one gameplay is decided that is to collect appropriate rocks, build castles and use other rocks to attack the opponent’s castle.
8. In step 12, the extracted elements are reimagined as game elements. Rocks can naturally become resources, and actions that can be performed on rocks can become mechanics. The gameplay idea already provides the clues. In step 13, rocks of different kinds become different resources. Rocks that can be used for construction, for attack and as precious currency are identified. Some rocks are given fantasy properties such as they can evaporate, catch fire etc. Fantasy properties are separately scored as magic powers and indicated through its higher cost.
9. In step 14 and 15, a system of mechanics is designed. The core mechanics are a collection of rocks, building of castle, storing the previous rocks, discovering magical rocks, preparing rocks for attack. The opposition mechanic comprises building rock shields for defense, looting precious stones, hiding sources of rocks etc. The decisions from steps 8 to 14 are indicated in figure (5.8).

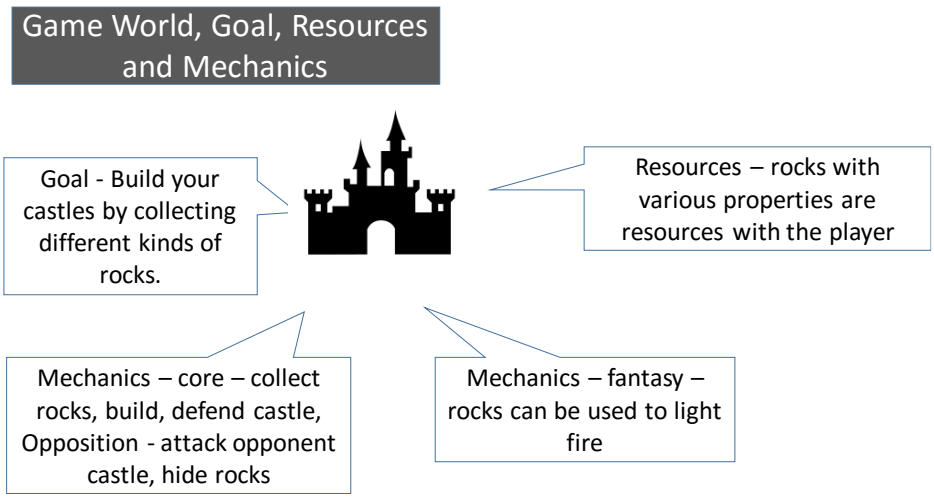



Figure 5.8 Game of Rocks - Gameworld, Goals, Resources and Mechanics

10. In step 16, learning affordance is reviewed. Figure (5.9) indicates the learning incorporated in the game elements. Since the associations are broadly in place, step 17 is skipped.

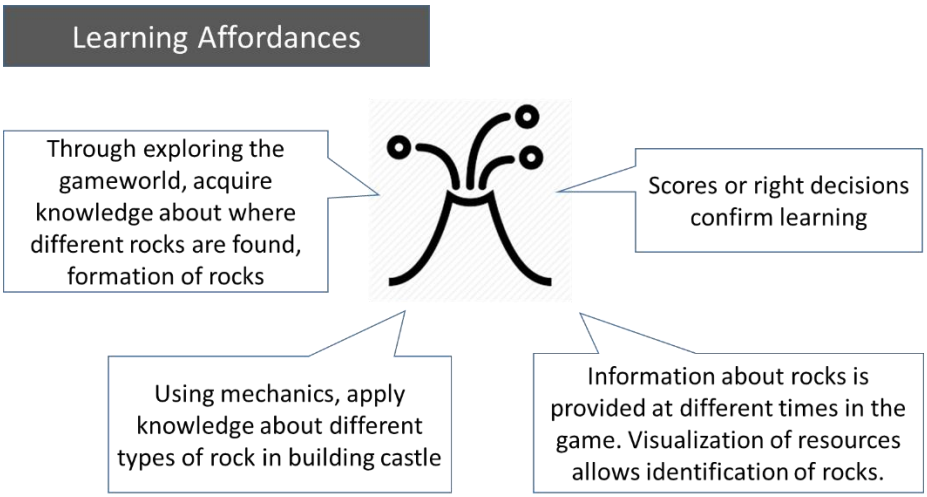
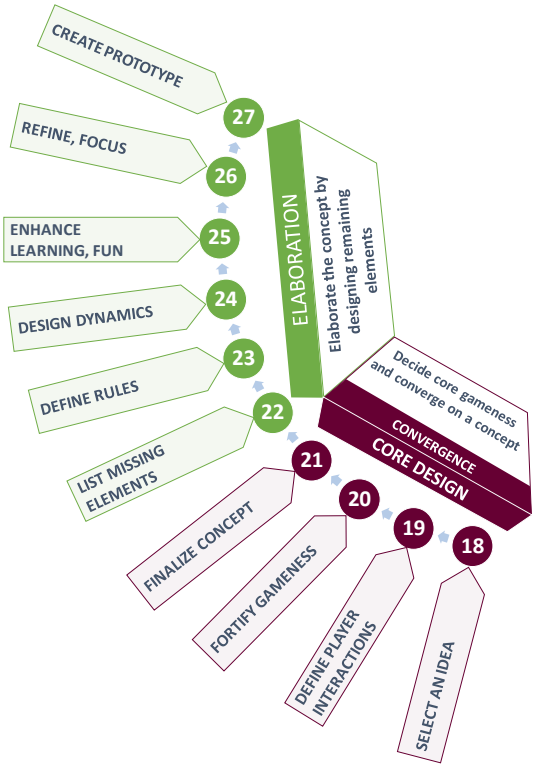


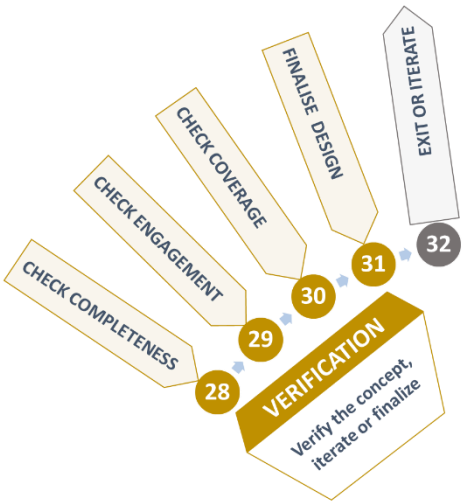

Figure 5.9 Game of Rocks – Learning Affordances

11. Since only one idea is selected, there is no shortlisting as in step 18. However, the idea is discussed with school students in the vicinity and since it was found fun, it is retained.
12. In step 19, the player interactions are decided. It is decided that the game will be played in teams with each team having multiple members. The players in the team interact with each other to develop, collect, store rocks, and build castle walls, weapons and defense systems. Some players defend the castle from attacks and some have to attack opponent's castles to get new sources. Some players have keys of hidden treasures and some have magical powers to unlock.

13. The economics of the game is through possession of rocks having different value and these can be traded with friendly kingdoms or used to buy other resources such as water, for survival.
14. At step 20, the gameness already exists in this concept. There is already a contest. Fun elements of hiding and discovering exist. In step 21, the concept is documented. In step 22, the missing elements are listed. These are mainly the rules.
15. In step 23, rules are defined for different roles and powers. Values are assigned for different stones. Criteria for movement are decided. The design of dynamics in step 24 is skipped.




16. In step 25, learning alignment and affordances are rechecked. The authenticity of learning is clearly demarcated from the fantasy elements of the rocks. The scores from each go in different buckets. There are also reinforcement messages or clues for right choices– e.g. which rock has which properties etc. Visual design of this concept is not done in this session.
17. The steps 26 (prototype creation) and steps 27 to 30 verification stages are not carried out in this design exercise. The designer finishes the concept in step 31 and moves to reflection on endogenous elements. The mechanics and resources are endogenous but gameplay is non-endogenous since it is taken from another known game but the resources were.




This example provides an idea of how the strategies can be used for endogenous design of educational games.

### 5.2.3 Potential Users and Usage

The core utility of our framework is in the synthesis of educational games. The framework and the embedded strategies answer different sets of questions, as sampled in figure (5.10) that designers face during synthesis.

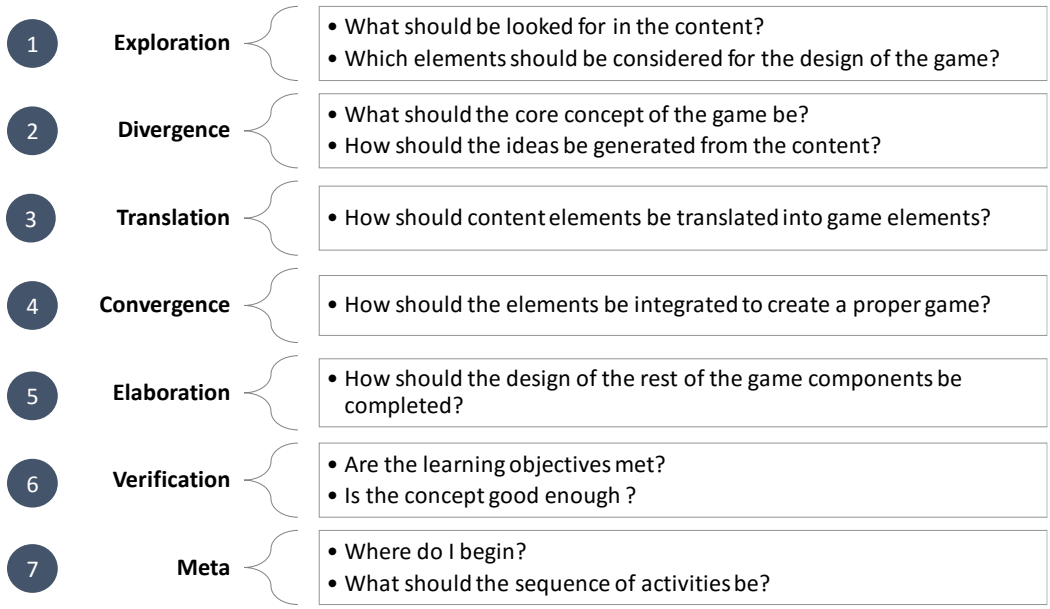



Figure 5.10 Sample Questions Addressed by the Framework

The framework answers simple questions that novices ask, such as the sequence of steps, to the more intricate ones such as the creation of a system of mechanics. It answers different questions that designers pose in each stage of the process. For example, a question 'How do I generate ideas from the content elements?' is addressed in the divergence stage. 'Is the concept good enough?' is addressed in the verification stage. Game designers, academicians and students can benefit from the framework in different ways as indicated further.

**Novice Game Designers:** Educational game designers who have just begun designing games can find this framework most useful. The framework provides a guided path, apart from specific strategies at every step. The details provided at each step ensure that very little in the design process is missed. Designers, who have designed games but not educational games, can find the framework an easy introduction to educational game design.

**Experienced Game Designers:** Designers who have experience in designing educational games can use this framework to achieve endogenous designs. Without access to knowledge about methods of endogenous design, designers are likely to create exogenous designs as reported by several authors. Hence, there is value in using the proposed strategies.

If the designers do not wish to use the guided path, the framework provides enough flexibility to use only specific strategies. Experienced designers may also use the fast track option to skip steps where they do not need support. Experienced designers can also contribute by making suggestions to improve the framework.

**Game Design Students/Teachers:** Game design students can use the framework as an educational toolkit for learning about educational game design. They can use the framework as a reference to complete the assignments. The teachers can use the framework as a teaching aid to augment their regular coursework. They can make modifications to the framework based on their experience.

**Educational Technologists/Instructional Designers:** Education technologists often need to use game-based learning media. They either rely on known game examples or consult game design experts for support. While they can continue taking support, this framework can help them become independent in designing game concepts.

**Learners:** Learners can use the framework to create games on their own. They can translate content into game elements and derive fun just by that act. They can build full concepts and prototypes as well, which can be used in their peer groups. In one of the informal pilots, a 7$^{th}$ grade student who found the topic of 'Rocks' in geography boring in textbook, reported it to be exciting when he translated it to a game.

**Game Analysts:** Game analysts can add this framework and the evaluation rubrics to their kitty of instruments. The framework kit consists of rubrics for evaluation of 'endogenousness', novelty, potential engagement and potential learning. The rubrics are provided in the appendix {A7}. The rubric on endogenousness is offered for the first time through our work. Rubric to measure novelty is also not commonly available. The rubric on novelty will need further improvements over time. However, rubrics for measurement of potential engagement and learning are available in the existing literature. We have adopted few elements from those, in our rubrics. Further, the design process in the framework acts a checklist for important steps necessary in game design. The game description template acts as a checklist of components necessary for completion of game concept.

### 5.2.4 Challenges in User Adoption

Freshly minted frameworks face challenges during user adoption mostly due to mismatch of expectations. We discuss how the Endogen framework addresses some of the diametrically opposite demands, which create these challenges.

**Freedom and Structure:** JC Jones [1977] challenged the utility of design methods including his own earlier proposals. He said, "I dislike the machine language, the behaviourism, the continual attempt to fix the whole of life into a logical framework". Indeed design practice is amorphous and has a significant human element in how it unfolds. Designers yearn for freethinking and dislike being tied down by processes. The notion of 'framework' can convey structure and constraints to them. However, structures and processes are important as well, as they bring assurances towards achieving outcomes. The Endogen framework offers balance between structure and freedom. Designers have the choice between using the complete process and using only selected strategies.

**Novelty and Conformity:** New frameworks are expected to conform to established standards and yet offer unique value to the designer. The novelty in the case of Endogen is the set of strategies for endogenous design. Existing frameworks offer guidance on integrating pedagogic elements with gameplay, but Endogen provides systematic guidance for extracting, translating, and integrating content elements into the gameplay. The conformity of new framework comes from relatedness to the practices known to designers. Since the synthesis of Endogen is based on the data collected from practicing designers, there is a high probability that designers will be able to relate to it.

**Specialization and Generalization**: Endogen is an instance of generic design processes studied by Gericke and Blessing [2011]. The generalised approach inherited by Endogen consists of steps such as breaking down problem space into elements, connecting these elements to make them ready for consideration in design, generating solution themes and then transforming these elements to fit into the solution themes. Downstream, Endogen can be specialized and adapted for adjacent purposes such as for a new segment of learners or new type of content. In the next section, we discuss such possible variants of the Endogen framework but these are not part of the current scope.

**Liberty of Design and Constraints of Authenticity:** In an attempt to make learning fun, designers may take creative liberty to introduce fantasy elements in the game. During translation, some of the content elements and the context may be modified to make the game interesting. However, care needs to be taken that this does not compromise the authenticity of content. In such a case, the onus is on the designer to ensure that authentic elements are specified and reinforced. Endogen framework guides designers to create fantasy elements during gameworld design but has a step in later stage to check the authenticity of learning.

**The Whole is not a Sum of the Parts:** Composing a game from elements is akin to composing music from basic notes. The Delft Design guide [Van Boeijen et al., 2015] suggests that design guides are like recipe books, which provide information about what needs to be done, but do not guarantee tasty food. The Endogen framework is no different in its positioning. It provides essential ingredients for endogenous design of games but does not guarantee the outcomes. The framework will enable designers to extract, translate and connect the elements but the onus is still on them to create a good game. The 'gameness' i.e. the core essence of any game cannot be created by collecting requisite elements. The designer has to find that creative ingredient, in the form of a unique rule or a contest or a challenge that a player will find worth playing.

### 5.2.5 Possible Extensions in Future

Using our framework as a baseline, researchers can create extensions of the framework in future. Addition of strategies for newer purposes, creation of a simplified version, and a digital version are among the few possibilities. The extensions may lead to wider user adoption. However, beyond enlisting the ideas, the extensions are not part of our current work.

**Digital Version of Framework**

In today's world where everything is moving to 'digital', a digital version of the framework would be a natural migration. A digital version will be more adaptive for users with different needs. Pattern recognition programs can be developed to apply exploration strategies on the source content and build a list of extracted elements. Algorithms can then recommend relevant game elements using pre-populated libraries of mechanics, resources etc. The designers can creatively integrate these recommended elements to realize working games. An early imagination of the app with the features discussed here is indicated in figure (5.11). A digital version will also have inherent advantages such as performing automatic checks on essential elements, enabling collaboration between designers and versioning of design ideas.

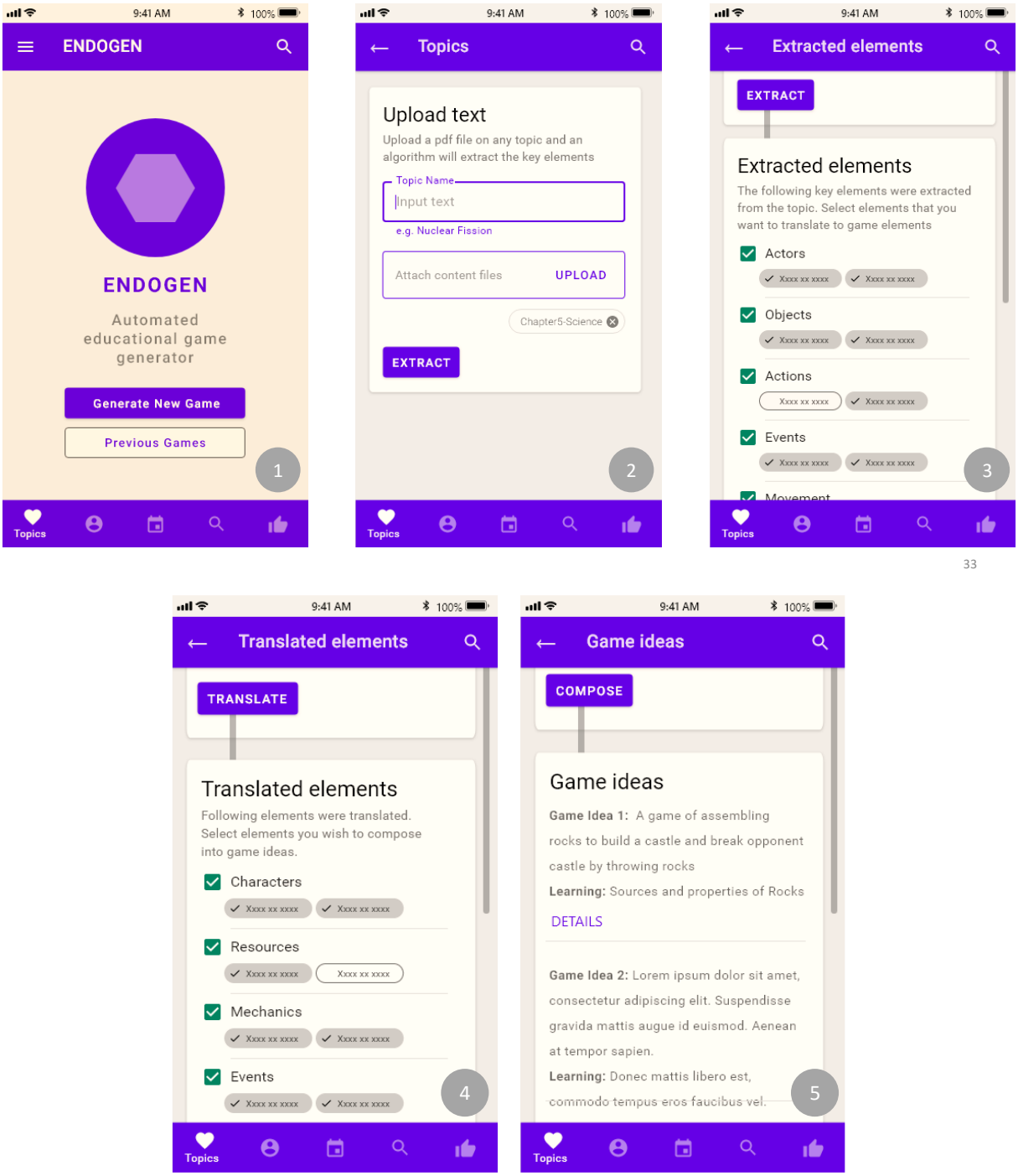



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Figure 5.11 Imagining Future Endogen App

**Simplified Version of Framework**

A simplified version can be created in the future to cater to users who do not have game design background. This version can have fewer steps, essential details and simpler terminology. The framework can be layered, starting with simpler levels. A digital version will be better suited to offer such graded approach.

**Extending the Set of Strategies**

The existing set of strategies can be extended in following ways in future:

a) Strategies specific to the segments – The current set of strategies is discovered with the middle school segment as reference. Strategies that cater to specialized segments such as engineering, commerce can be identified.
b) Strategies specific to the types of content – Additional strategies specific to the content types (factual/procedural/conceptual) can be discovered.
c) Strategies catering to the other dimensions of learning – Learning is not restricted to mental faculties such as cognition, behaviour or physical skills. Games can be designed for learning situational awareness, interpersonal behaviors, problem-solving, creativity, resource management, risk taking etc. Strategies can be added for the same.
d) Strategies catering to specific mediums – The current framework is agnostic to the medium of game but there can be specific strategies that utilize the capabilities of technologies such as Augmented Reality (AR) and Virtual Reality (VR), which can be added.
e) Strategies for ideation – Ideation strategies were excluded from the framework, as these are available elsewhere. Adding these can make the framework better suited for users who do not have design background.
f) Instructional strategies – In Endogen, the insertion of pedagogic principles is hinted in one of the steps, but explicit strategies to deal with scaffolding, assessment, feedback, progression, mastery etc., could be incorporated in future.
g) Strategies for repurposing existing entertainment games – It is possible that existing games which are popular, can be repurposed for education. New strategies will be required to address such post facto integration.
h) Applications in new contexts – The proposed strategies can be tested in new contexts such as designing games for health care, sustainability. Appropriate strategies relevant to these contexts can be added.

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**Summary of Chapter**: In the earlier chapters, the need for a framework, discovery of strategies and the synthesis of Endogen framework was discussed. In this chapter, we presented the validation of framework and discussed its potential adoption. We also presented the possible extensions that can be a part of future research. In the next chapter, we summarize our research to conclude the thesis.

# Chapter 6 **Conclusion**

In this chapter, we conclude the thesis by summarizing our work, stating our contributions, acknowledging the limitations and sharing a direction for future work.

## 6.1 Bird's Eye View

In the introduction chapter, we began with a discussion on the issues that impact adoption of educational games. For the purpose of this thesis, the scope was narrowed down to the problem of design. Through our research, we proposed a framework for endogenous design of educational games. The 'Endogen' framework aids improvement in the quality of the design and can therefore enable better adoption of educational games. In the light of this new research, we take a bird's eye view of the educational game design space to understand the interconnections, boundaries and opportunities.

At times, the term 'Educational Games' appears to be an oxymoron as it simultaneously brings the connotation of seriousness and playfulness to the mind. In our research, we addressed the question of how these can coexist. We stepped back and asked why they need to coexist or should there be a separation of concerns? The answer according to Crawford [2003] is that games are meant to be educational and have always been so. A quote from his work makes a profound impact on the proponents of educational games.

> "Games are the most ancient and time-honored vehicle for education. They are the original educational technology, the natural one, having received the seal of approval of natural selection. We don't see mother lions lecturing cubs at the chalkboard; we don't see senior lions writing their memoirs for posterity. In light of this, the question, "Can games have educational value?" becomes absurd. It is not games but schools that are the newfangled notion, the untested fad, the violator of tradition. Game-playing is a vital educational function for any creature capable of learning." – Crawford.

Crawford's argument can, however, be countered knowing that humans have evolved more than animals. Humans have developed a variety of cuisines while animals are still stuck with raw meat or plants. Similarly, methods of learning also evolved into more sophisticated, scalable, efficient means in the form of books and classrooms. Hence, games could have been relegated to the back seat. Nevertheless, we appreciate his assertion on the value of 'play' in learning.

The constructionist paradigm of learning insists on constructing meanings. Play offers the best opportunity for learners to experiment, experience and construct pieces of knowledge. 'Microworlds', which are interactive, exploratory learning environments, similar to a sandbox, made of a subset of a domain can enable learners the freedom to explore and make meanings. However, can freeform play in 'microworlds' accomplish purposeful learning? Play by nature is unconstrained and it is likely that the learners may be diverted from the original purpose. They may still learn something but not necessarily achieve the intended objectives. That is where games have a role. Games offer structured play, bound by goals and rules.

Championing or achieving mastery is an important motivation to play any game. The player is essentially learning the context and the rules, to utilize them for winning a game. How can the same structure deliver education effectively? The structure can enable learning and playing simultaneously if the learning content is built into the gameplay. This deep integration of content into the gameplay requires endogenous design, wherein the game elements emerge from the content elements. Creating games with such endogenous design would not be easy without appropriate guidance. Our Endogen framework now offers the required guidance to the designers in the form of a process and a set of strategies.

Endogenous design is a desirable but not a sufficient condition for adoption of educational games. People play games voluntarily only when the games are fun and rewarding in some way. In the Endogen framework, we broadly suggested that fun could be generated through the design of a unique contest, challenge, rule, arrangement, or novel use of resources. However, designing fun is a research topic in itself, which is under-addressed. Due to a dearth of elaborate guidance on designing fun, designers today follow a thumb rule: play as many games and understand the fun to reapply it in a new game. Designing fun that is endogenous to educational content requires sound observation and creative abilities. The Endogen framework makes this task easier by providing the ideas and the gear, but the mountain is still there to be climbed.

Learning is not only about knowledge application, which games predominantly do. Other facets such as knowledge creation, knowledge acquisition, and knowledge evaluation make up the larger gamut of the learning landscape. Among these, knowledge creation is typically a function of research, and educational games do not occupy this space yet. Our validation studies have confirmed the utility of the framework largely in the knowledge application space, and to some extent, in the knowledge acquisition space. The framework has not specifically dealt with evaluation. The limit of the Endogen framework to support all these spaces needs to be tested.

Learning habits are changing with time. New-generation learners may not be seeking to acquire content but may want to search and apply it ‘just in time’. Is the idea of educational games catching up with such changes? Instead of monolithic games that help learners acquire content, mini and micros games that deliver at the point of application of the knowledge may need to evolve. How does the Endogen framework remain relevant in such a scenario? We believe that the proposed strategies would still be largely useful, but newer strategies may be needed to design ‘gamelets’. For example, a strategy that helps breaking-down the content into smaller bits for conversion to mini games, and another that helps create continuity between these gamelets can be tried.

Ever-changing technology is pushing the boundaries of what we understand as games today. Upcoming mediums of delivery such as Augmented/Virtual Reality offer new faculties such as teleportation, participative simulation, and collaboration. Designing games for such media requires the knack for extracting content elements that can exploit the power of these mediums. For example, teleportation to geographically important sites such as volcanoes, glaciers, the equator and the poles can change the way geography is learnt.

Ubiquitous games or games around us are played using an array of sensors and devices placed in the neighbourhood. How would such games help in learning? Imagine a history lesson taught by visiting different places of historical importance, where the game progresses as the learner visits these places and performs certain game activities. Researchers have the opportunity to extend the Endogen framework to exploit such technologies.

The Endogen framework intends to democratize the act of designing educational games. It may not be feasible for a small community of game designers to create effective games for the vast landscape of educational domains. Therefore, teachers and learners can be enabled to create their own games. Use of technology can augment this democratization process. Digital Apps can provide in-process support to anyone wishing to design an educational game. Artificial Intelligence and Machine Learning can be used to gradually learn the patterns in the content and recommend appropriate game elements. The designers can then simply glue these elements meaningfully to create a playable game. Endogenous design strategies of the present and future will be the backbone of such a technology intervention.

Frontiers of endogenous design can also be pushed in lateral dimensions such as designing games for change and games for healthcare. ‘Games for change’ encourage behavior change for a sustainable environment, good citizenship, and healthy habits among other things. The content in these domains is in the context. A sustainable environment may have content in the form of documented best practices, but the focus is on translating the situations, behaviors and interventions in these contexts to game contexts. Similarly, in healthcare, websites already provide rich information on rehabilitation or medication. Designers are expected to translate the constraints and enablers in these contexts to game contexts, and not simply translate the information.

In summary, the Endogen framework is a worthwhile beginning to address the current and future challenges in educational games. Upcoming researchers will need to extend and advance the frontiers to adapt the framework to evolving needs.

## 6.2 Summary of Thesis

Our research was guided by the motivation to make learning interesting using educational games. In the first chapter, we began with a discussion on the issues related to unrealized potential of educational games. Poor integration of content and gameplay was identified as one of the issues. Inappropriate integration leads to games that are neither educational nor enjoyable. Designers can however create better integrations with appropriate guidance. The significance of our research is in creating this guidance on 'intrinsic' integration of content and gameplay, also termed as endogenous design. The research questions we posed in section {3.1.1} are addressed in Chapters' 2 to 5.

In the second chapter, the foundation for our research was laid. This included understanding game design, learning paradigms, content types and instructional design. We discussed the intersection between games and learning through the models available in the literature. These models focus more on integrating pedagogic goals rather than content elements with the game. We discussed the pitfalls of poor integration and identified endogenous design as an approach for better integration. In 'endogenous design', the game elements are generated from the content elements. The current state of knowledge and gaps in endogenous design were discussed. Initial experiments with endogenous design gave us cues on the kind of strategies that lead to endogenous design.

In Chapter 3, we presented our approach and methods to discover strategies. Design Based Research (DBR), was used as an overall research methodology. DBR was chosen since our intention was to develop a framework of strategies for practical use. Using Protocol Analysis, we planned to study design practice and discover the strategies. We conducted pilot studies to confirm the choice of methods and the research design. After that, the main studies were conducted and the data generated was analyzed using coding techniques. Study of design activity allowed us to gather the heuristic based design strategies used by the participants. The strategies emergent from the analysis were discussed.

In Chapter 4, the synthesis of the Endogen framework was detailed. We articulated our approach for the synthesis of the framework, which is based on the Function Behavior Structure approach. The strategies discovered earlier were refined and organized into a process, before including into the framework. This framework is the core contribution of our research.

In Chapter 5, we described the methods used for validation of the framework and the results. Using a multi-method approach, framework was validated for its utility, on four dimensions. Overall, the framework met the objective of enabling endogenous design and providing end-to-end guidance on design process. The studies also provided feedback for improvement. In the second part of the chapter, we described the challenges in user adoption and indicated how Endogen attempts to address them. We also listed ideas for future extension of the framework.

## 6.3 Key Findings and Contribution

The summary of findings and contributions of our work is presented further.

**Design Strategies**

The key findings from our studies are the strategies for endogenous design. The strategies for content exploration enable identification and extraction of 'gameable' elements from the content. These elements could be actors, actions, objects, events, movements, situations, conflicts, contrasts, phenomenon and more. The strategies for translation enable the designers to translate these identified elements into game elements such as resources, mechanics and gameworld. Additional strategies help in taking core design decisions, concept detailing and verification. The findings address our core research question: 'What are the strategies for endogenous design of educational games?' This is one of the first attempts to present elaborate strategies for endogenous design of educational games.

**Endogen Framework**

The key contribution of our research is the framework for endogenous design of educational games. An important goal of design research is to understand the phenomenon of design and use that understanding to prescribe better design processes [Blessings and Chakrabarti, 2009]. The Endogen framework achieves this goal.

The framework provides a guided process with a set of strategies at every step of the design process. The strategies organized in a framework offer significantly enhanced practical value, which was confirmed through validation studies. This comprehensive process enables designers to cover essential aspects of design. It addresses basic questions that novices ask, such as "where do I begin", to the more intricate ones such as "which elements of the content should I consider for the game". Though the framework is well suited for novices, experienced designers can use selected strategies.

**Commentary on Endogenous Design**

We conducted a survey of educational games literature from an endogenous design perspective. By contrasting endogenous and exogenous designs, the need of endogenous design was argued. We also proposed that the concept of endogenous design is not binary but a continuum with varied degrees. An instrument to measure the 'degree of endogenousness' of educational games was developed as well.

**Additions to Design Research methods**

The overall research was guided by the Design Based Research (DBR) methodology. We created customized implementation of the DBR and applied it to study educational game design. The Protocol Analysis was also adapted and extended to study game design practices. Function Behaviour Structure (FBS) approach was used for the synthesis of framework, thereby creating a case for use of FBS in synthesis. We also contributed to methods for validation of design frameworks. We enlisted and addressed various issues related to user adoption of new frameworks. Both, validation and adoption of design frameworks is inadequately addressed in the current literature.

## 6.4 Limitations of Our Research

Our research was specifically oriented towards addressing the design problem in the educational games space. The limitations of our work arise out of the decisions on the scope of research, research design, as well as due to shortcomings recognized in validation studies. These are as follows:

**Scope**

We restricted studies to the educational topics for the middle and high school segment. While the strategies discovered for this segment can be extended to other segments, at present the strategies are tested for middle school topics. Additionally, our focus was to study development of game concepts rather than full-fledged playable games. Studying the creation of concepts provides adequate coverage of design strategies. However, studying the creation of playable prototypes could have provided supplementary feedback about the impact of strategies. In addition, the educational games can span across knowledge creation, acquisition, application and evaluation. Our studies focused on acquisition and application.

**Research Design**

We conducted studies with ten participants. Each study was done with a single participant per session with a three-hour duration. The participants were selected to represent variation in gender, background and locations (throughout India). The small-sample design was suited for deep qualitative research such as understanding thought processes in our case. However, discovery of few additional strategies cannot be ruled out with a larger participant base, more design time, more variation in topics and covering locales other than India.

**Framework**

The validation studies pointed out certain shortcomings of the framework. The suggestions for layout improvement have been accounted for in the thesis. Suggestion to rearrange the stages, as well as to create layers, will need additional research in future.

**Effective Educational Games**

We have relied on existing literature to support the underlying view that endogenous designs are effective. However, additional studies may be necessary to identify any contexts where endogenous designs may not yield desired results. Another feature of the current work is its exclusive focus on content. While this is an essential and core concern for endogenous design, design of learning games requires integration of pedagogic principles as well, which earlier frameworks such as LM-GM have addressed.

**Validation Studies**

Our claims can be strengthened further through validation from the wider community of educational game designers.

## 6.5 Future Work

Our research is one of the first attempts to devise strategies for endogenous design of educational games. The research has created multiple possibilities for future work, discussed in section {5.2.5} earlier. We summarize the possibilities here:

**Improvements and Extensions**

The set of strategies can be extended in a variety of ways in future. With additional research, strategies for specific type of content, for specific disciplines such as engineering, commerce etc., as well as for specific technology such as virtual reality, can be discovered.

Different flavours/structures of the framework can be created to suit users having different needs, for example, creating a simplified-layered version for users having lack of design background. Presently, the framework addresses the design of educational games, but the strategies can be extended for designing games for other contexts such as health and wellbeing.

**Digital Framework and Game Generation**

A digital version of the existing framework is a certain possibility. The digital version can be made adaptable to users with different needs and abilities. Using the design strategies as the backbone, a program can automate some of the steps in the process. Pattern recognition algorithms can possibly extract relevant content elements. Once extracted, the pre-set strategies combined with Artificial Intelligence, can translate them to game elements. Considering the advances in computational creativity, in future it may be possible that the programs combine the game elements in novel ways.

**Adjacencies**

Endogenous design is just one aspect of making educational games more prevalent. Designing 'fun' in educational games remains more art than science, and hence a potential research topic. Designing educational games that align to changing learning habits, emerging technology and newer learning contexts are possible directions for future research.

## 6.6 Revisiting Motivation

The genesis of our thesis is the underlying motivation of 'making learning interesting'. The problem we chose to address was of design, and specifically that of endogenous design of educational games. Games with endogenous designs have the potential to make learning fun. Acknowledging the lack of endogenous design strategies in prevalent literature, we embarked on the journey to identify them, by studying design activity. Our curiosity was aroused in the discovery of the 'gameness' in the content.

Our work has made specific contribution toward identifying strategies for endogenous design. These strategies are organized in the form of a framework for better practical consumption. Novice game designers can find great value in this framework to kick-start their careers in educational game design. Learners can use the strategies as well, to reimagine the content and 'play' with it to make their own learning interesting.

# Acknowledgements

Many people contributed in small and big ways in the pursuit of my PhD.

Firstly, I am grateful to my supervisor Prof. Girish Dalvi for his continuous guidance and motivation. His systematic, meticulous and honest approach has not only left an impact on my work but also made my PhD journey efficient. I would like to thank Prof. Uday Athavankar, for shaping my ideas and challenging the work from time to time. Thanks to review committee members Prof. Sridhar Iyer and Prof. Ravi Poovaiah for asking right questions, providing direction and encouragement during every formal or informal meeting. I would also like to thank Prof. Pramod Khambete for triggering the idea of PhD and for discussing varied aspects about doing research.

It was not easy to do a PhD while being employed full time. However, TCS CTO unit is a special place where doing PhD was encouraged and time-off is allowed for course work. I would like to thank my supervisor at TCS, Mr. Vivek Balaraman for facilitating organizational support. I thank my colleagues at TCS, especially Mr. Sachin Patel for sharing workload and our team for their cooperation when I could share lesser time with them. I would also thank Dr. Shailesh Deshpande of TCS, who was always willing to provide practical help on the 'process' of doing PhD. Thanks to Dr. Smita Ghaisas (my neighbour at work) for hearing out work issues and offering advice when needed. Thanks to Mr. Nishal Kumar for help in statistical tools, Ms. Freya Barua for editorial review. Thanks to Dr. Mayuri, Dr. Jayasree, Dr. Jamwal for insightful discussions, advice on social science research methods and reviews.

The insights presented through this work could not have been possible without the data provided by the participants in the several studies. I would like to thank Mrudula Gadgil, Akash Mohan, Sanket Pai, Prapti Verma, Silpa Murali, Akshay Goel, Hrishi Oberoi, Gaurang Gheewala, Ashwanth Thotta, Satyajit Chakraborti, Vasundhara Agarwal, Greg Acuna, Shikha Verma, Ketaki Gokhale, Ravi Mahamuni, Gokul, Radha Soman, Bhaskar Das, Varnika Naik, Vijayanand Banhatti, Siddharth Sarkar, Radhika Verma, Shree Nivas, Malay Dhamelia, Ulfa Khwaja, Lakshmi Ganesh, Anurag Deep, PC Herold. All of them spent their time and effort for preparation and participation in design sessions. Special thanks to Mr. Malay, Mr. Sanket, Ms. Soumya, Ms. Kavya, Mr. Anthony William (NID) for their support in organizing workshops.

I would also like to thank the panel of evaluators, which included Mr. Ameya Athavankar, Mr. Aakash Johry, Ms Manisha Mohan and Mr Dileep Mohanan. Sincere thanks to Mr. Sylvan Lobo and Mr. Akhil Guthula for support in graphics. I would also thank my PhD colleagues for keeping our group's morale high, as well as friends and staff at IDC, and staff at IIT main building for administrative support. I will remember Aahar catering for providing homely food at IDC.

I appreciate the good wishes of my present and past colleagues, teachers and friends. Special thanks to friends at Ruturang for keeping me cheerful. Thanks to the youngsters around who participated in game testing. Thanks to Mrs. Kolhatkar, Ms Swati Abhyankar, Mr. Manoj Soman, Ms. Meera Babre, Mr. Aditya Gokale and Mr. Tejas Kelkar for their specific support. I thank my relatives, in laws who believed in me and contributed in ways that allowed me to focus on my work. Thanks Vinay for being there in Mumbai.

Last but not the least, I appreciate my wife Rajashri and my parents, who supported my efforts and cared for me, as they always do. I commend my (now grown up) kids Shivani and Soham who adjusted their usual expectations from me.

Though I tried to capture most names, I fear I may have missed a few important ones, as it was a five-year long journey. I will thank them in person.

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# Publications by the Candidate

**Papers in Conferences**


1) Athavale, S., & Dalvi, G. (2020). Endogen – Framework for Designing Endogenous Educational Games. In Digra International Conference 2020
2) Athavale, S., & Dalvi, G. (2019). Strategies for Endogenous Design of Educational Games. In Digra International Conference 2019: Game, Play And The Emerging Ludo-Mix.
3) Athavale, S., & Dalvi, G. (2019). Discovering Strategies for Design of Purposeful Games—A Preliminary Study. In Research into Design for a Connected World (pp. 63-74). Springer, Singapore.
4) Athavale, S., & Dalvi, G. (2018, May). A method to study purposeful game design process. In 2018 IEEE 6th International Conference on Serious Games and Applications for Health (SeGAH) (pp. 1-8). IEEE.
5) Athavale, S., & Mohan, A. (2018). Understanding game ideation through the lens of creativity model. In DS 89: Proceedings of The Fifth International Conference on Design Creativity (ICDC 2018), University of Bath, Bath, UK (pp. 176-182).
6) Athavale, S. (2017, October). Conceptualization of Purposeful Games. In Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play (pp. 679-682). ACM.
7) Athavale, S., & Agrawal, V. (2017, July). Bringing Game Design Models to Life. In International Conference on Human-Computer Interaction (pp. 3-20). Springer, Cham.
8) Athavale, S., Johry, A., & Dalvi, G. (2015). Can fun and purpose coexist in a learning game? A case study of a novel geometry learning game. In edulearn15 Proceedings (pp. 2839-2848). IATED.

# Appendix A: Research Preparation Documents

## Appendix A1: Session Plan Checklist

The table below indicates the activities conducted before, during and after session

| Activities | Details |
|---|---|
| **Advance Preparation of Participant** | Participant was provided short notes on 'what is a game', 'what is a purposeful game', the 'essential attributes of a game' and methods of creative thinking a few days before the session. |
| **Consent** | Information about think aloud protocol is provided to the participant and a formal consent for audio-video recording is obtained from the participant. |
| **Environment Setup** | Planning of room, recording equipment and material is done |
| **Session schedule for Participant** | Time for settling down, practice session, researching topic, divergent thinking, convergent thinking, closing and documenting. |
| **Design Brief** | Given at the beginning of session, the Brief contains expected outcomes, learning objective, scope and references |
| **Game Description** | Participant writes the game concept description in the format provided. This helps evaluators refer to standard description headers. |
| **Researcher Activities** | There is minimal intervention from the researcher in the think-aloud session apart from reminding the participants to think aloud.<br>The researcher notes the remarks during the session, specifically when the participant does not explain the rationale for decisions. This is asked post session. The demographic profile of participant is pre-recorded. |
| **Interview** | At the end of session, a brief interview is conducted to understand some of the decisions taken by the participant. A video walkthrough is done if necessary. |
| **Evaluation** | Participant is requested to conduct self-evaluation of the concept.<br>Evaluation panel is appointed in advance and they evaluate the concept after the session using rubrics provided to them |

## Appendix A2: Participant Handout for Experiment

[The handout guides the participant about the session using a question answer format.]

1. What is the goal?
   - Design a game concept that imparts learning to the intended audience through playing of the game for the topic shared with you (refer to design brief)
   - While designing you have to think aloud all your ideas, steps, actions. Researcher will remind if you stop speaking your thoughts.

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2. What would be the medium of game?
   The game should preferably be designed for digital medium but if you feel other medium is better, go ahead. In any case, you have to demonstrate concept on paper. You can demonstrate concept using sketches and any supporting material.

---

3. What should you try during design?
   - Attempt cohesion between gameplay and learning – this means try to create a gameplay which emerges from the content and not superimpose existing gameplays on that
   - Avoid imitation of existing games
   - Cover sufficient elements form the content but it is not necessary to cover everything.
   - It is alright to introduce fantasy as long as it does not twist the real learning elements

---

4. What is the expected outcome?
   - A game concept that can be reasonably explained so that the player understands it
   - **Take all possible decisions (don't keep open ends – like either this or that)**
   - Identify basic rules such as to begin, move, score and end the game
   - Components such as objective, core mechanics, opposition mechanics, dynamics, resources should be identified (refer to game concept description sheet)
   - Prepare a sketch
   - At the end of session, please complete the game concept description document

---

5. Session plan (desirable)
   - There will be a trial run for first 10 minutes.
   - You have 2 hours, 40 minutes approx. for concept creation,
     - First 15 to 20 minutes you can spend understanding the content
     - In the 1st hour it is advisable to think of multiple alternate concepts
     - Evaluate and select one concept
     - Next one hour you can detail one concept
     - Next 10 minutes you can write the game description document
   - There will be a 10 minute interview at the end to discover missing aspects from think aloud
   - At the end of interview there will be evaluation session – you will evaluate the game of four parameters as well as two other designers will evaluate on same parameters.
   - You can take bio breaks, but please avoid phone calls/chat and avoid talk to other people about ideas during the session

---

6. Material provided
   - Blank sheets, chart paper, pencils, erasers, sketch pens, rulers, color papers, scissors, dice, cut cards and tokens, Lego pieces or ask for more and that will be provided if available

## Appendix A3: Sample Design Brief

[This document provides the problem statement for designers]

**Topic x: Geography - Rocks and Soil**

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**Goal**: Design a game that imparts learning.

**Audience**: School Grade 8th

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**Topic**: Rocks and soil

In grade 8, students are expected to learn about Rocks, type of rocks, properties of rocks, rock cycle and sources of rocks. Similarly, they learn about soil. They may also learn about uses of the same. However, memorizing about various names for different types of rocks and soil and relating them in any known context is not easy for the students. Can a game help them? Design a game to help students know the facts about rocks and soil.

You can use Internet to search about the topic further.

1. http://cart.ebalbharati.in/BalBooks/ebook.aspx [Search for Geography Standard 8]
2. https://www.haverford.k12.pa.us/Page/11046
3. Any other

---

**What should the players learn?**

1. Know different types and properties of Rocks and Soil
2. Know formation of rocks and soil
3. Know use of various Rocks and Soil

---

**Medium of Instruction**: English

## Appendix A4: Game Concept Description Template

[This is the template to be is filled by participant at the end of the session]

Participant name: Date:

Age/Gender: Education:

Game Design Experience:

| | **Aspect** | **Example Game** | **Your game Concept** |
|---|---|---|---|
| 1 | Name | Entangle | |
| | Description | Entangle is a board game for learning basic shapes and angles in Geometry. The game is for 3 players, each using a set of sticks. The board has an array of slots equilateral shaped and the players place the stick on one of the places in their turn. The dice decides the action player has to take. Once a stick is placed and a shape/angle created, the player picks up the shape-card from the bank. The card has scores. The players accumulate scores and maximum score wins. | |
| | Learning | Geometry Shapes and Angles | |
| | Audience | 6th standard | |
| | Objective in the game | To create/identify shapes and angles and collect points | |
| | Game world | A board of equilateral triangles | |
| | Players/ characters | 3 players | |
| | Player Control | Players have to place sticks intelligently to claim max scores | |
| | Core mechanic – the main activity that moves the game forward | Create. Place sticks to create shapes. | |
| | Opposition mechanic – the counter force for movement | The complexity of the array | |

| | | | |
|---|---|---|---|
| | Dynamics (elements that change with time) | The complexity increases with every stick placed.<br>On certain dice values, the player can remove sticks of opponents and reduce their score to bring balance | |
| | Resources – equipment, lives, spaces, tokens, currency, etc. | Array board<br>Sticks of 3 colors<br>Dice<br>Score shapes | |
| | Inter player interactions | Call out identified shapes and collect scores. Other players can watch missed shapes and claim on their turn | |
| | Elements of engagement – curiosity/ chance/ fantasy/ challenge | Chance through dice, Challenge due to entangled shapes, Curiosity due to which shapes emerge | |
| | Elements that help learning | Score shapes have printed shape and name | |
| | Cohesion | Act of placing sticks and collecting score shape is integral to gameplay. No separate learning activity | |
| | Novelty | | |

## Appendix A5: Researcher's Ready Reference

[This document is a reference for the researcher to set up the session as well as during session]

**Advance Activities**

1. Appointment with participant and evaluators
2. Send rubrics to evaluators
3. Send preparation material to participants
4. Procure material
5. Book open space (having no disturbance)
6. Take consent

**Just Before Session**

1. Set up audio, video
2. Keep a watch available for timekeeping
3. Make internet access available

**Beginning of Session**

1. Note data about participant (age, gender, profession, creative inclination, liking for playing games, digital games)
2. Session instructions to participants
3. Conduct trial run
4. Share the design brief
5. Divergence and convergence nudges
6. Ask for sketches
7. Fill game description document

**After Session**

1. Participant to fill evaluation sheet
2. Interview
3. Evaluators to evaluate (setup times)

**Researchers Note Taking Sheet**

[This document is a template for taking notes during session]

Participant #____Name of participant:

| **Time Starting (mins.)** | **Observations, Questions** | **Problem Domain (C )/ Game Comp (G) / Process (P) / Others (O)** |
|---|---|---|
| 0 | | |
| 15 | | |
| 30 | | |
| .. | | |
| .. | | |
| .. | | |
| 150 | | |
| 165 | | |

## Appendix A6: Questionnaire for Post Session Interview with Participant

Participant # ____ Name: _____

1. Domain
   1.1 How did you study the domain/content? Which parts were studied?

   1.2 Which aspects of the domain were considered useful for game design?

   1.3 Which aspects were considered - time constraints, spatial movement, people interactions, real world rules, objectives?

   1.4 Where did you begin – what was the first thing about domain that came to mind

---

2. Gameplay
   2.1 Which game ideas came to mind first?
      - What were the triggers?

   2.2 Why do you select this (the final) idea as the best fit for the purpose?
      - Why did you eliminate other ideas?

   2.3 How did you decide on the opposition mechanic?

---

3. How did you bring specific elements of content into gameplay?

---

4. Did you twist/modify any part of the reality to create the game? Which parts?

---

5. Process
   3.1 Which places in the session were you stuck?

   3.2 Which strategies did you use to overcome the issue?

   3.3 Where did you get inspiration?

   3.4 Which techniques did you use for idea generation?

# Appendix A7: Evaluation Rubrics

## 1. Rubric for Measuring Endogenousness

Presented in the section {2.8}

## 2. Rubric for Measuring Novelty

| | None | Low | Moderate | High | Rating |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | |
| **Novelty in Gameplay** | The game concept is mostly an imitation | The game concept is mostly an extension/variation of existing game | The game concept fits in the existing genres but has some differentiators | The game concept is new and unrelated to existing games | |
| **Novelty in Learning through playing** | Learning is through question/answer, assistant, cue cards | Most learning is through cues and help and some application is through mechanics | Most learning is through mechanics and some is through cues and help | Learning is through the mechanics, strategy in the game | |
| **Novelty in transformation of content to gameplay** | The transformation is obvious as in simulation game | There is some novelty in transformation - eg the game world and goals or some part of interactions are novel | There is lot of novelty in goal, mechanics, world and interactions are derived from the content | Entire gameplay- goals, mechnaics, world is transformed in a novel way | |
| **Novelty through use of Outside (the context/ box) elements** | No outside elements or inspiration is used | There is minor inspiration from unusual sources | There is inspiration from unusual sources (esp. sources other than existing games) in some parts | There is significant of inspiration from unusual sources (zeugma like) | |
| **Overall (interpreted not weighted)** | | | | | |

## 3. Rubric for Measuring Potential Engagement

This is a measure of how well this game concept can engage players. This is about the potential and not actual achievement.

| | Does not exist | Low | Moderate | High | Rating |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | |
| **Curiosity** | | | | | |
| **Challenge** | | | | | |
| **Chance, luck** | | | | | |
| **Multiple paths for progress** | | | | | |
| **Inter player contest/conflict** | | | | | |
| **Rewards for performing/learning well** | | | | | |
| **Balance - Opportunity to come back and win at various times in the game** | | | | | |
| **Attractive Visual /representation** | | | | | |
| **Overall (interpreted not weighted)** | | | | | |

## 4. **Rubric for Measuring Potential Learning**

This is a measure of how well the game concept can support learning of the intended topic. This is about potential and not actual

| | None | Low | Average | High | Rating |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | |
| **Knowledge acquisition** | The player will not be able to acquire intended knowledge through gameplay | The player will be able to acquire minor knowledge through gameplay | The player will be able to acquire reasonable knowledge through gameplay | The player will be able to acquire most desired knowledge through gameplay | |
| **Knowledge Application** | The player will not be able to apply intended knowledge through gameplay | The player will be able to apply minor knowledge through gameplay | The player will be able to apply reasonable knowledge through gameplay | The player will be able to apply most desired knowledge through gameplay | |
| **Curiosity about exploring more** | The game does not create curiosity about learning more | The players can mostly proceed with minimal or initial learning and does not further the interest in learning | The game has few aspects that promote players exploration of content beyond the scope | The game has many aspects that promote players exploration of content beyond the scope | |
| **Overall (interpreted not weighted)** | | | | | |

# Appendix B: Validation Interview Forms

## Appendix B1: Comparative Study - Participant Feedback Form

(A copy of this was used by the reviewer to review each participants work)

Please answer the questions below. Thanks for participating in the design session and your feedback.

**Name : _____ Age: Gender: Session**: Morning / Afternoon

1. **Ease of Use:** How would you rate the ease of use of the framework? The framework is…

- ☐ Very Easy to use
- ☐ Somewhat Easy to use
- ☐ Neither easy nor difficult to use
- ☐ Somewhat Difficult to use
- ☐ Very difficult to use

2. **Clarity**: The sequence and the design process suggested by the framework is….

- ☐ Very Confusing
- ☐ Mostly Confusing
- ☐ Partly confusing and partly clear
- ☐ Mostly Clear
- ☐ Very Clear

3. **Overall Utility**: How would you rate the usefulness of the framework in design of your concept?

- ☐ Very Useful
- ☐ Mostly Useful
- ☐ Partly useful
- ☐ Not much useful
- ☐ Not at all useful

4. **Angles of Attack:** 'The framework provoked me to think of multiple possibilities at every stage'. How much do you agree or disagree with this statement?

- ☐ Strongly Agree
- ☐ Somewhat Agree
- ☐ Neither agree nor disagree
- ☐ Somewhat Disagree
- ☐ Strongly Disagree

5. **Flexibility**: 'The framework allowed me to work on my own by altering sequence or by skipping steps or adding new steps

- ☐ Strongly Disgaree
- ☐ Somewhat Disagree
- ☐ Neither agree nor diagree
- ☐ Somewhat Agree
- ☐ Strongly Agree

6. **Detail**: The guidance provided by the framework at each step of the design process was….

- ☐ Very detailed
- ☐ Mostly detailed
- ☐ Partly detailed
- ☐ Mostly superficial
- ☐ Fully Superficial

7. **Completeness of Concept**: The guidance provided by the framework helped me in designing….

- ☐ All the essential components
- ☐ Most of the essential components
- ☐ Some of the essential components
- ☐ Few of the essential components
- ☐ None of the essential components

8. **Exploration**: How would you rate the guidance provided by the framework for exploration/ extraction of content elements?

- ☐ More than adequate
- ☐ Adequate
- ☐ Partly Adequate
- ☐ Mostly Inadequate
- ☐ Inadequate

9. **Translation**: The guidance provided by the framework in translating content elements to game elements was….

- ☐ Inadequate
- ☐ Mostly Inadequate
- ☐ Partly Adequate
- ☐ Adequate
- ☐ More than adequate

10. **Ideation**: The guidance provided by the framework in generating ideas for various game elements was….

- ☐ More than adequate
- ☐ Adequate
- ☐ Partly Adequate
- ☐ Mostly Inadequate
- ☐ Inadequate

11. **Endogenous design**: How do you rate the endogenous-ness of your concept?

- ☐ Highly Endogenous
- ☐ Mostly Endogenous
- ☐ Partly Endogenous
- ☐ Mostly Exogenous
- ☐ Exogenous

12. **Novelty**: How do you rate the novelty of your concept?

- ☐ Very different from known games
- ☐ Mostly different from known games
- ☐ Partly different from known games
- ☐ Mostly similar to known games
- ☐ Very similar to known games

13. **Fun to play**: How do you think players will find your game?

- ☐ Mostly boring
- ☐ Somewhat boring
- ☐ Neither boring nor fun
- ☐ Somewhat fun
- ☐ Mostly fun

14. **Coverage**: How much of the content was covered in your game?

- ☐ All elements of content
- ☐ Most elements of content
- ☐ Part of the elements of content
- ☐ Few elements of content
- ☐ No elements of content

15. **Participants Learning**: How much did you learn about educational game design in today's session?

- ☐ I learnt a lot of new things
- ☐ I learnt a few new things
- ☐ I did not learn much

16. **Time**: The time available for concept creation was

☐ More than Adequate ☐ Adequate ☐ Less than Adequate

## Appendix B2: Validation-Focus Group Questionnaire

Welcome, as you are aware the purpose of this session is to collect feedback about the framework.

Setup Discussion – I would ask a question to one person in rotation but request others to contribute on each question. I will also moderate if the discussion is veering away. Feel free to share your opinions, and feedback on each.

1. Can you describe your experience with game design prior to this session?
   *Sub Qs: What kind of frameworks have you used? Are you aware of frameworks for educational game design?*

2. How was your experience of using this (Endogen) framework?

   *Can you elaborate on what aspects you found it good and which aspects it did not help?*
   *Sub Qs: Ease of Use, learning, time/effort required, flexibility*

3. Which parts of the framework did you find most useful?
   *Sub Qs: Exploration/Translation/Game ideation/Completion*

4. Can you describe aspects you could have done/have done even without framework and aspects where you would have struggled without the framework?

5. How many ideas could you generate and how did he framework help?

6. How would you describe the information on the board and cards – was it inadequate, adequate or overwhelming?

7. Which parts of the content could be translated to the game and how did the framework help? How much content could you cover?

8. Which kind of topics do you think this framework can help create games?
   *E.g. Conceptual, factual, Procedural Topics*
   *Topics for behavioural learning*
   *Or classify based on constructivist, behaviourist*

9. Which kind of topics do you think this framework cannot help create games?

10. Which type of users can use this framework to create games?
    *E.g. Students, Teachers*
    *Sub Q - What changes if any are required for academicians to use it?*

## Appendix B3: Validation-Longitudinal Study Questionnaire

[This interview was conducted when the longitudinal assignments were submitted back]

Name: _____ Game - _____Interview Date: _____

Welcome, Thanks for participation again.

1. Approximately, how many days/time per day did you spend on design and how many times did you use the framework?

2. Can you describe how you used the framework in long studies?
   *You had it always by the side when you designed or referred to it separately from design activity or you kept the cards available or you had some parts of the framework ingrained*

3. Comment on your Understanding of the framework.

4. Level of Detailing of Framework – which parts are well detailed? Less detailed, over detailed?

5. How many stages of the framework did you complete?

*6.* How would you compare the use of framework in the single session you participated versus when you had it with you for longer period

*7. Does (and how does) the framework help in Endogenous design*

*8.* What shortcomings have you found after using the framework for a longer period

9. Which parts of the framework did you find most useful?
   *Sub Qs: Exploration/Translation/Game ideation/Completion*

10. Comment on the design process you followed

11. What additional guidance should have been included in the framework?

12. Will you (and how will you) use the framework in Future

13. Any other comments:

# Appendix C: Coding Sheet

The column headers indicate participant and topic; cells represent the observed data and row headers indicate the codes extracted from that row.

| Main Study | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 | Pilot 1 | Pilot 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Participant | P1 (M 30) | P5 (F 26) | P3 (F 26) | P11 (M 23) | P6 (M 35) | P7 (M 35) | P12 (M 45) | P8 (F 28) | P9 (M 45) | T1 (F 35) | T2 (M 30) |
| | **Some experience** | **Trained but inexperienced** | **Trained but inexperienced** | **Self learned inexperienced** | **Experienced** | **Experienced** | **Experienced** | **Some experience** | **Experienced** | **No experience** | **Trained but inexperienced** |
| Design Task | Game for learning Fundamental Rights (Civics) | Game for learning Heat (Physics) | Game for learning Rocks and Soil (Geography) | Game for learning Mensuration (Maths) | Game for learning Heat (Physics) | Game for learning Current (Physics) | Game for learning Mensuration (Maths) | Game for learning Current (Physics) | Game for learning Reactions (Chemistry) | Game for Traffic rules awareness | Game for Digital banking awareness |
| Content type (mainly) | Factual | Conceptual | Factual | Procedural | Conceptual | Conceptual | Procedural | Conceptual | Procedural | Practical | Practical |
| **Extraction** | | | | | | | | | | | |
| Elements extracted from the content | Properties of rights, keywords | Phenomenon Properties of substances, Examples | Properties, sources, uses of rocks, phenomenon (cycle) | Shapes, lines, Problems | metal, water, expansion, contraction, friction, heat and cold | water flow, battery, charge move in line, one direction | Examples (already gamified) | Examples, electrical components, cells | Molecules and properties, Reactions and types | Actors, Objects, Rules, Behaviors, Layouts | Persona, transactions, processes, safety |
| Striking elements | 1. The pervasive nature of rights 2. Situations that demand knowledge of rights | 1. The properties of substances change when they are heated/cooled | 1. Identification of rocks and usage | 1. Larger shapes are made of arrangement of shapes (and holes) | experiments/action, transfer of heat | Examples | Borders | Moving charges, switch, magnets, recharge | Shapes of molecules and how they attach to each other, Exercise | Movement Breaking rules | Transactions, give and take, |
| Human in the context | People can know, use, trample, create, protect rights | People use heat | People extract, use different kinds of rocks | Not observed | Move the metal | not used | Where do people use areas and perimeters | | Humans create chemicals for use | Humans have goals, they may break rules, they may be vulnerable | Humans produce goods, trade, receive money, invest money |
| Contest candidates | Blocking rights vs using rights | Heat/cold, expansion/contraction, freeze/flow | Not extracted | Expanding areas vs limiting | Heat vs cold, expansion vs contraction | | correct calculation vs wrong cal | Moving current, blocking current, conductor/ insulators | Not extracted | Following vs breaking rules | buy vs sell |
| Boredom elements | Dry description | Not observed | Dry description | Repetition of calculations | | | learning without context | | just making circuit complete | Following rules | Mere transactions are boring |
| Extraction Approach | Passthrough and Keywords | Chunking and Examples | Pass through | Problems | chunking | multiple passes | | interactive elements | Systematic | Systematic, List | Imagination |
| **Translation** | | | | | | | | | | | |
| Type | Mix of simulation and fantasy world | Mix of simulation and fantasy world | Fantasy | Object centered - Manipulation of Physical properties | Fantasy | Fantasy | Fantasy | Physical, representation | Visualization, simulation | Simulation | Simulation |
| Fantasy | Mix of history and current issues, landforms | Personification of concepts/ objects | Rock tunnel | No Fantasy | Chracter on mission | Ant world | Profession/ tile factory | | No Fantasy | Some unreal elements | Fantasy village-market narrative |
| Primary Emergence | Player Choices | Resources (materials), changes | Resources (rocks) | Resources primary, and opposition mechanics | Resources, tools | Resources (moving ants) | application context | components, flow | Resources, mechanics | Goal, resources, mechanics | Transactions |
| Mapping | Mechanics - obstacle race | Mechanics - obstacle race | Steal, recover, build | Mechanics are "arrange" - standard for shapes Fun - standard economy models | Properties to puzzles, actions to game actions (mechanics) | Charges to Ants, battery to super ants, ants generate magnetism when in motion | | circular movement | Share/Hide chemicals | Mechanics - race | Financial transactions to game transactions |
| Combining game and content lements | | | | | Reading a hidden message using molten metal, opening a door knob by heating | | | | | | |

| Main Study | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 | Pilot 1 | Pilot 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Participant | P1 (M 30) | P5 (F 26) | P3 (F 26) | P11 (M 23) | P6 (M 35) | P7 (M 35) | P12 (M 45) | P8 (F 28) | P9 (M 45) | T1 (F 35) | T2 (M 30) |
| **Game Detailing** | | | | | | | | | | | |
| Gameplay | Two players have to cross the board having multiple landforms and situations (which need rights) to reach destination | Players have to play against a system and pass through channel using heat and cold as tools | Player have to dig tunnel, recover different rocks and build artefacts. Opponent has to replace stones dug out back inside tunnel | Players have to arrange the shapes on a grid to form larger shapes and claim points for area/ perimeters | Role play where player is on the mission like trasure hunt and uses inventory on the way for tackling obstacles | Ants move on a wire and have to kick out super bugs. They move over lava which is like magnetism generated by movement of ants | Make tiles and fulfil orders by doing calculations | Create the circuit, move the charge and blow the bulb, block the circuit of opponent | Two players have to complete two diff reactions using available chemicals. They can cooperate or refuse. | Players have to reach destination first using routes in the city and following rules - they may face situations where rules need to be broken | Players produce goods and sell in online market |
| Medium | Board/Digital | Digital | Digital | Board | Digital | Digital | Digital | Board | Digital | Digital | Digital |
| Goal | Reach destination by negotiating situations | Reach destination by negotiating cold/hot situations | Dig out stones from tunnel to create items vs replace stones back in tunnel | Own areas and perimeters | Complete the mission | Mission to oust dicatator ant | Higher ratings and good earning | Glow the bulb | Build chemical equations | Reach destination | Earn money |
| Movement | Character | Material | collection | assembly | character | Ants (charges) | orders | move charges on circular path | | | |
| Core Mechanic | Obstacle race - Situation resolution | Obstacle race | Collect | Arrange | Obstacle race - use heat and cold to overcome | stable wire for movement of ants | make tiles, calculate needs | collect cards, connect, move charges | Puzzle solving | Race | Trading |
| End game | Reach destination first | Points in Time limit | Points in Time limit | Pieces exhausted/ currency exhausted | Complete the mission | oust dicatator ant | | Glow the bulb | Guess the outcomes or the inputs | Reach destination first | Max money |
| Opposition Mechanic | The situations challenge the rights and block the movement which can be overcome by use of rights cards | Different materials block the path and can be overcome by using heat and cold to shrink or expand etc. Time | The opponent refills the opened rocks from tunnel and blocks further progress. Catching wrong rocks has penalty | Opponent can place holes or their own cards to block creation of larger areas | Obstacles | narrative based - movement on moving wire | poor ratings on incorrect calculations | Block others circuit | Time | Time, Pay off matrix - which forces | Inherent tussle between producing, selling and buying |
| Resources | Board, cards | Metal, water, heat, cold. Recharge by touching energy stops Powers | Rocks of varios kind, time | Shapes, cards, money, Board | Heat, cold, metal, water, | diff types of ants | Tiles, money | Electrical components | Molecules, Energy, Clues, Equipment | Bikes, Equipment, Money, | Money, goods |
| Scoring | Morality meter | Heat points | No of items created/not allowed to create | Areas and perimteres claimed - impacts learning | Coins collected for right decisions | | Ratings on good performance | | Points on reactions completed | Points and penalties | Money, inventory |
| Economy | | Trading heat points | Possesion of rocks | Possession of money, trading of cards | Coins for trading materials | | Starting funds, earn and spend on raw mat | trade of components/ cell | Chemical compunds exchanged | None | Trading |
| Fun elements | Heaxogonal array Landforms In digital version the color of character can change based on morality | Continouos manipulation, strategy | Time pressure to identify rocks and pick/replace them | Standard - trading, blocking, economy, achieving challenges (target shapes) | Puzzles that can be solved by using concepts of heat and cold | Keeping ants on the wire | More choices | Random draw from bag | The assitant and master can work collaboratively while trying their own outcomes | Reporting other players for violations | Mechanism to produce goods like pots etc |
| Alternate Gameplay ideas | 1 Building a pyramid of rights with fundamental rights at the bottom etc. 2 Journey through lufe stages 3 - Historical movements | 1- Board game with path and use of cards to pass through the path 2- make a recepe 3- using physical materials 4- fire fighting mission 5- endless runner kind - water has to be kept flowing despite varios temp zones | explored but did not matured - Some narrative based on rock cycle. | 1- Card games to complete formula, 2- Manufacturing belt and assembly of objects | 1- Fast paced game where players have continously balance the material in solid liquid and gas state 2 - Actual physical game with real components and burners etc | 1- dominos | 1- plantation game 2- card game with area blocks to calculate total area | 1. Practical live setup of elctrical components 2 - Physical game where people act as components and move charges like passing the parcel | Question answer cards | None. All were within same larger idea | Chicken as investment and eggs as interest |

| Main Study | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 | Pilot 1 | Pilot 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Participant** | P1 (M 30) | P5 (F 26) | P3 (F 26) | P11 (M 23) | P6 (M 35) | P7 (M 35) | P12 (M 45) | P8 (F 28) | P9 (M 45) | T1 (F 35) | T2 (M 30) |
| **Learning Delivery** | | | | | | | | | | | |
| Learning via | Reflection, Reinforcement, Application | Reinforcement, Application | Repetition | Recall, Reinforcement, Application | Feedback | analogy | trial and error | application | Recall, Reinforcement, Practice | Observation | Practice, analogies of security, passbook etc |
| Learning activity | Information application | Visualization of concepts | Visualization, Identification | Visualizations, Calculations | Application | | Calculations | application | Visualization, combinations | Virtual activity | Experience |
| Coverage of learning - how | Template game - any scneario-rights can be added | Thinking of one element for each concept | Time boxed (whatever fits in time) | Gradual increase of scope | Template - scenarios as puzzles | | | | Template game. More reactions can be added | Systematic | The core |
| Limitations | game master required for deciding correct answer | Core concepts - "why" not handled | Limited scope. Covered only one third | The word problem part was not covered well | Acquisition is not covered | Indirect learning | | | Initial knowledge has to be provided as hints | Learning is not clearly called out | |
| Learning Preq/acq | | | | | Animation | | Search help on formulaes | | | | |
| **Process** | | | | | | | | | | | |
| Initial Approach | Thinking scenarios where rights are needed | Simulation, animation of phenomenon | Connections between sub topics | Generate ideas from the go | Refered to experiments, thought of digital game | immediate ideas | contextualize | listing elements | 3D world objects, film makimg type of approach | Listing elements of content, trial and error | Analysis of the problem space |
| Ideation techniques | Used some generation techniques | Used some generation techniques | Not observed | Not observed | Not observed | Focus on some elements | contextualize | | Film making | Not observed | |
| Outside Inspirations | Pyramids, History | Cooking, Fire fighting | Not observed | Objects around, factory | | objects around, analogies | | | | | |
| Prior Game referenes | Fable, Jenga | | Not observed | Power Grid | Treasure hunt, clash of Clans | | Bob the builder | prior board games | Cut the rope, Scrabble | Racing cars, monopoly | |
| Convergence approach | | | | | | | | | | | struggle |
| Rationale | The situation game appeared more apt than physical object games | More paths for replayability, more player control | Cud only close one idea | Going back to first idea | Digital game is comfortable | Digital game is comfortable | contextual game | | Only one idea generated | | Digital is better to learn digital transactions |
| Challenges Faced | "The topic is gloomy - hence difficult to create fun " "Using alternate ideas may distort reality" | Deciding right idea for convergence | translating rock cycle to game | How to make it fun for repeat play | explaining concept, | representing content truthfully | | Use of magnet | How to impart fundamental knowledge. (application is ok) | How to promote unruly behavior for sake of game, How to control movement? | Ideation |
| Scoping | | | | | whether to stay at gross level or select few at detail level | levels | | | | | |
| Possible Biases | Balanced approach | Use of physical properties, good divergence skills but low convergence | Not observed | Sample game of triangles | Digital games | Techniques used apriori | | IDC training | Animation and his own prior game | Domain experience | |
| **Outcomes** | | | | | | | | | | | |
| Endogenous nature | Mechanics are not endogenous. Player choices are | Use of physical properties and temperature zones brings forth endogenous nature | Collection of specific type of rocks is endogenous but only limited use of content | Use of connected shapes and holes to calculate area/perimeter brings forth endogenous nature | Use of content objetcs to uncover, unlock the path | The mechanics are not endogenous but the analogy is | Low on endogenousness the context is relevant but the learning is implanted | endogenous mechanics | Joining the molecules in endogenous | Goals, Mechanics, resources are all endogenous | Mechanics of transactions |

# Appendix D: Game Concept Sketches

In this appendix, we present the compilation of sketches for select game concepts created by the participants in our studies [The ideas remain proprietary of respective participants].

| #T1 | **Game Name: Safe Riders** | **Educational Topic:** Safe Driving Practices, Rules |
|---|---|---|
| **Description:** SafeRiders and is a multi-player digital game. Each player gets a set of three characters and one motorcycle to ride, limited safety gear and some currency to pay fines or use public transport. Motorbike accommodates two characters. Each player begins at a random location in the city decided by the system and has to reach the destination to attend a concert in time, navigating through the city traffic. To win the game, all the three characters of a player need to reach the destination before others. The player has to choose shorter routes, avoid restrictions, take risks and decide the optimal path for each of the three characters to travel faster. Non-compliant behaviours can attract penalties if caught and may result in accidents as well. Players can report violations of opponents to police officers at intersections. The players would thus learn about traffic awareness and safety in a fun way by playing SafeRiders. | | |
| **Endogenous Elements:** Objects (Vehicles, equipment), routes, rules, penalties, goals, gameworld | | |
| **Medium:** Digital | | |
| **Sketch:**   | | |

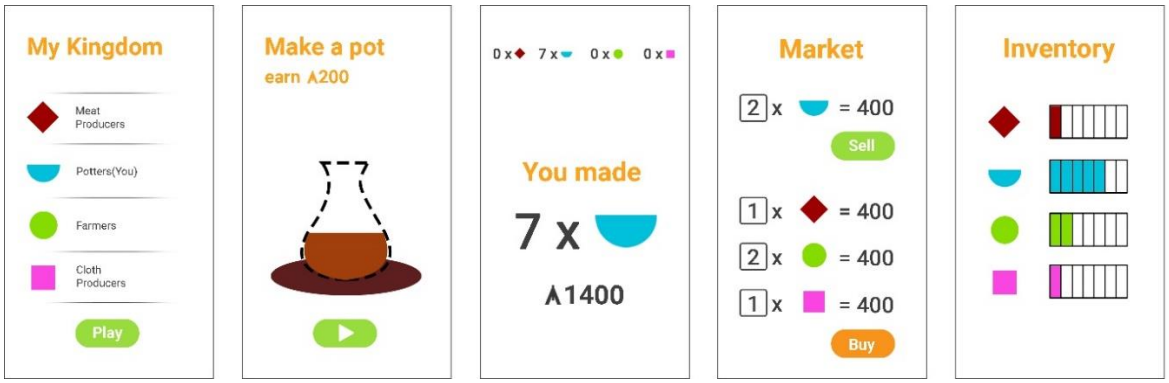
| #T2 | **Game Name: Village Square** | **Educational Topic:** Digital Banking |
|---|---|---|

**Description:** This is the story of digital villages, where villages are part of kingdoms. Each village has only one kind of people, who produce some kind of product and they trade with other villages and get other products in return. Thus, some village produces Food, some makes meat, and some make pots and other weave clothes. However, for the village to sustain it must have all the resources. In the marketplace, all the players ("villages") sell the goods that they made and buy the goods that they require for sustaining. Villagers can do the buy and sell transactions online using the currency of the kingdom. They can save money, take loans, see the balance etc.

**Endogenous Elements:** Digital Transactions, Professions, Banking Concepts

**Medium:** Digital

**Sketch:**



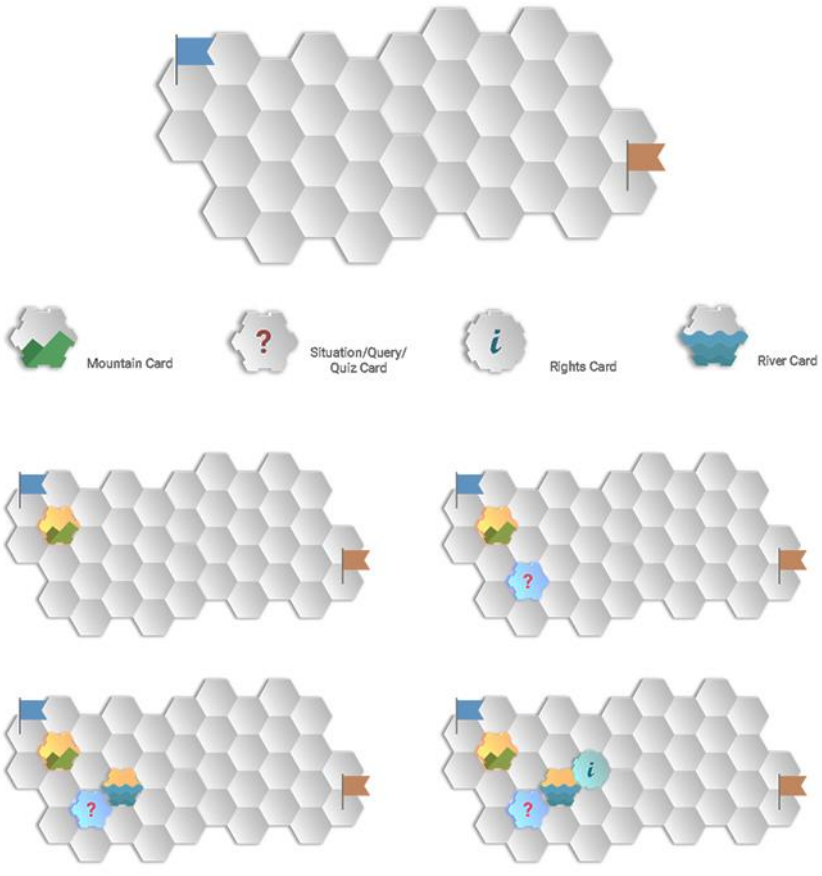
| #P1 | **Game Name: Rightway** | **Educational Topic:** Fundamental Rights |
|---|---|---|

**Description:** This is a game for learning fundamental rights. The game is for 2 players who play against each other. The game world is in form of a hexagonal cell board with some terrain elements, which can be constructed by players dynamically. The terrain features are used to block certain pathways. The players get a set of hexagonal fundamental rights cards, each can be used multiple times. They also get a fixed number of dealt hexagonal scenario cards from a larger stack. The play is turn based. First player places a scenario card on one of the hexagonal blocks connected to the block occupied by opponent token (each scenario to be used once). The opponent has a choice to then use either a 'rights' card to free the path or to use a longer path instead. If the wrong card is used then the player loses that card for the next two turns. The player who reaches opponents base first wins.

**Endogenous Elements:** Rights cannot be destroyed

**Medium: Board**

**Sketch:**



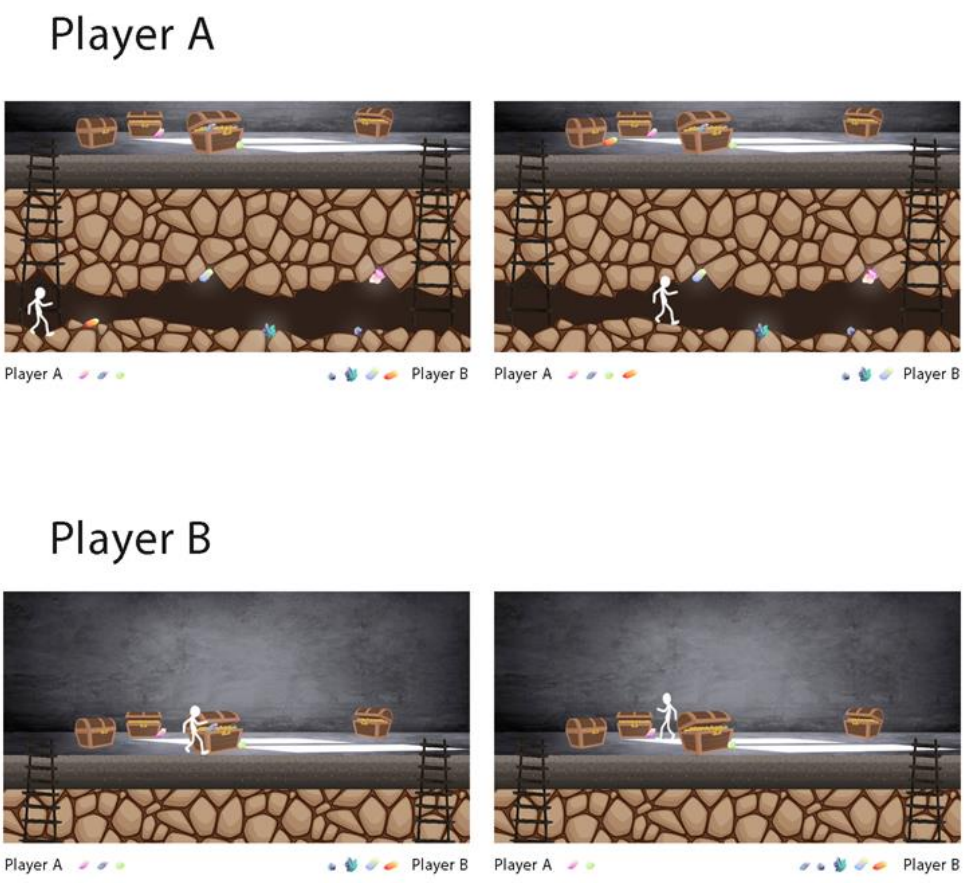
| #P3 | **Game Name: Rock Tunnel** | **Educational Topic:** Rocks (Geography) |
|---|---|---|

**Description:** This game is for identifying rocks based on their properties and uses. The screen shows a tunnel made of different types of rocks underground, and a set of objects (collectibles) which use those rocks above the ground. Timer starts, a rock type and its physical properties is shown in the info box, player A digs thru enough number of the said rock type, to steal the collectible highlighted above the ground. Clicking on wrong rocks, result in time penalty. Player B simultaneously clicks on the correct rocks to put them back in the tunnel and prevent player A from stealing the corresponding collectible. Rock type changes every 10 sec. At the end of 90 sec, the player with most number of collectibles on their side wins.

**Endogenous Elements:** Types of Rocks, Properties of rocks, uses of rocks

**Medium: Digital**

**Sketch:**



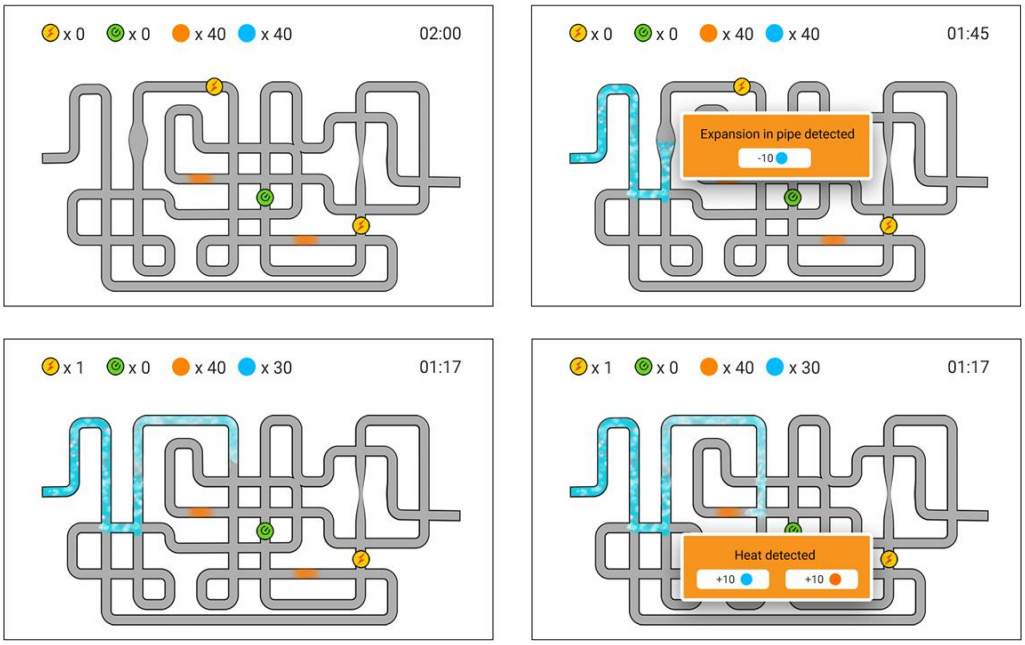
| #P5 | **Game Name: Heat-O-Mania** | **Educational Topic:** Heat (Physics) |
|---|---|---|

**Description:** Heat-o-mania is a game to demonstrate the concept of 'heat' in physics for children studying in 7th grade. It is a single-player, digital game wherein the player acts as a 'water' character whose aim is to cross a path filled with obstacles which can be overcome by using 'hot' and 'cool' points and 'powers' which are basically heat transfer concepts like expansion, contraction, convection and radiation. The obstacles include some temperature-based zones and a 'metal' character. The player must complete the game within a given time to proceed to the next level. At the end of each level, the player receives some 'hot' and 'cool' points.

**Endogenous Elements:** Properties of metals, water, insulator, effects of heat and cold

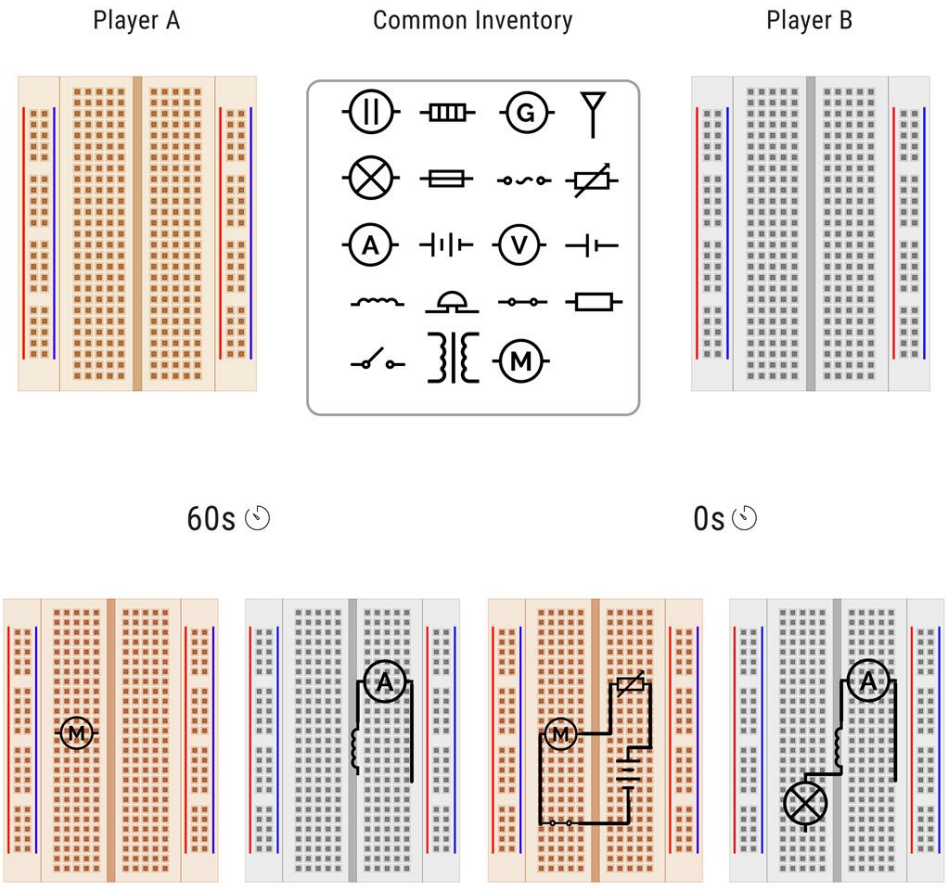
**Medium: Digital**

**Sketch:**



| #P8 | **Game Name: Circuit Spree** | **Educational Topic:** Electric Current (Physics) |
|---|---|---|
| **Description:** Circuit Spree is a game for learning about the various pieces that make a circuit. The game requires the players to collect the pieces of a circuit and complete it as fast as they can. Once the circuit is completed, the player can see flow of charge in the circuit through an external led circuit. Player has to make his/her own circuit while not allowing the opponent to make it. | | |
| **Endogenous Elements:** Electrical components | | |
| **Medium:** Physical board | | |

**Sketch:**



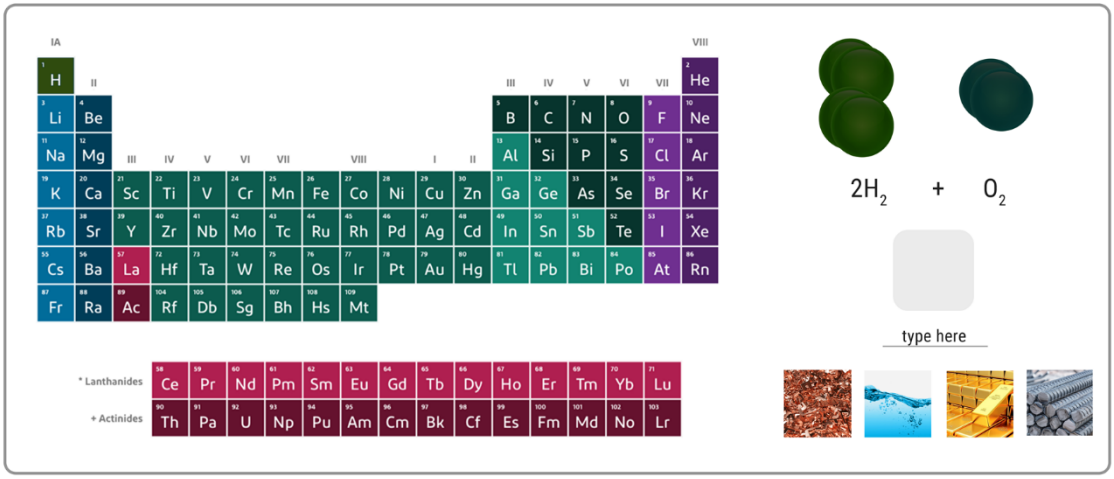
| #P9 | **Game Name: React lab** | **Educational Topic:** Basic Reactions (Chemistry) |
|---|---|---|

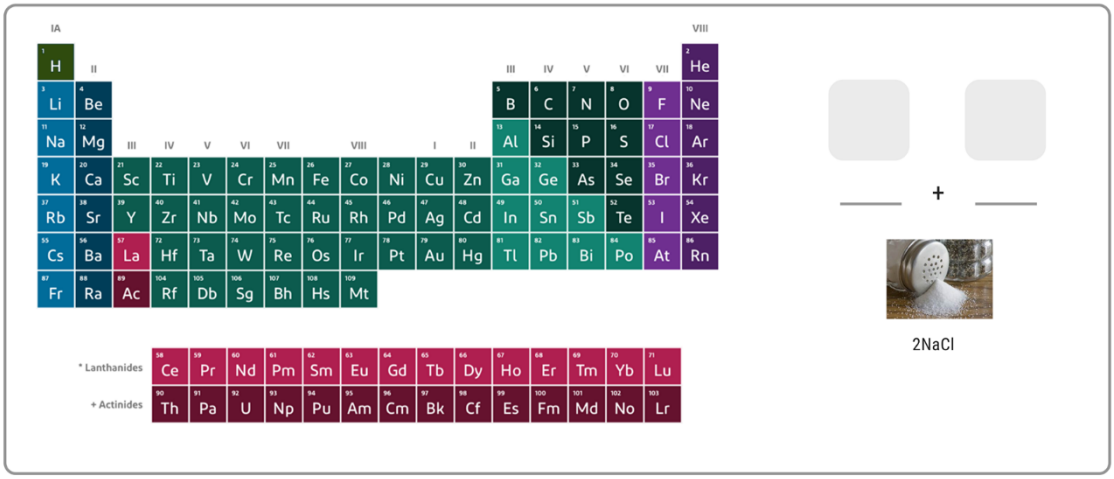
**Description:** It is a 3D world game where two players interact to build chemical equations using available resources. The material (molecules) is spherical in shape but has texture/color of the chemical itself. Players have to predict outcomes, if input part of equation is given in the form of 3D molecules. If the outcomes are given, then the players have to fill the equations with right input elements. There are two chemists (players) in the lab, solving their own equations. They may have to share materials, may help or deceive each other. The two players can act cooperatively or can have different competing goals.

**Endogenous Elements:** Molecules

**Medium:** Digital

**Sketch:**



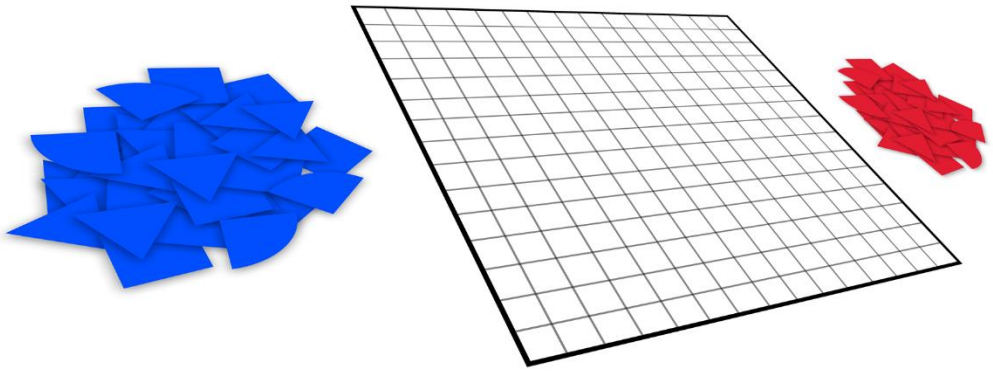
| #P11 | **Game Name: Shape Wars** | **Educational Topic:** Mensuration (Maths) |
|---|---|---|

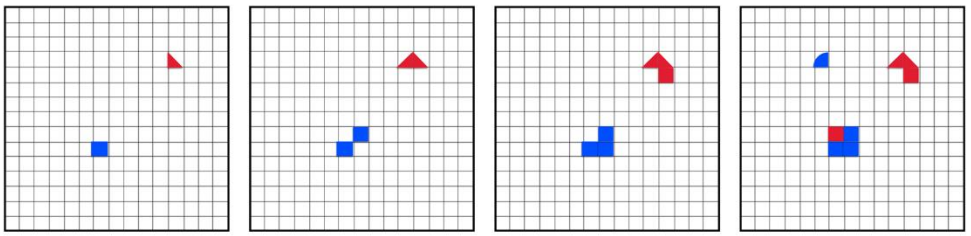
**Description:** The aim of the game is to teach calculation of area and perimeter of different shapes. A board game with two players (as opponents) where each player starts with a set of pre-cut shapes of varied sizes (as tokens) that can be placed on the grid to claim areas and perimeters. Each player has one color and has to maximize scores by creating continuous patterns. Opponent has to break the pattern by placing his color in the grid and reclaim areas by placing ‘voids’.

**Endogenous Elements:** Area and Perimeter of different shapes, Area with borders

**Medium:** Board

**Sketch:**





| | Area Covered | Patterns Destroyed | Area Covered | Patterns Destroyed | Area Covered | Patterns Destroyed | Area Covered | Patterns Destroyed |
|---|---|---|---|---|---|---|---|---|
| Player Blue | 1 | 0 | 2 | 0 | 3 | 0 | 3.78 | 0 |
| Player Red | 0.5 | 0 | 1 | 0 | 2 | 0 | 3 | 1 |

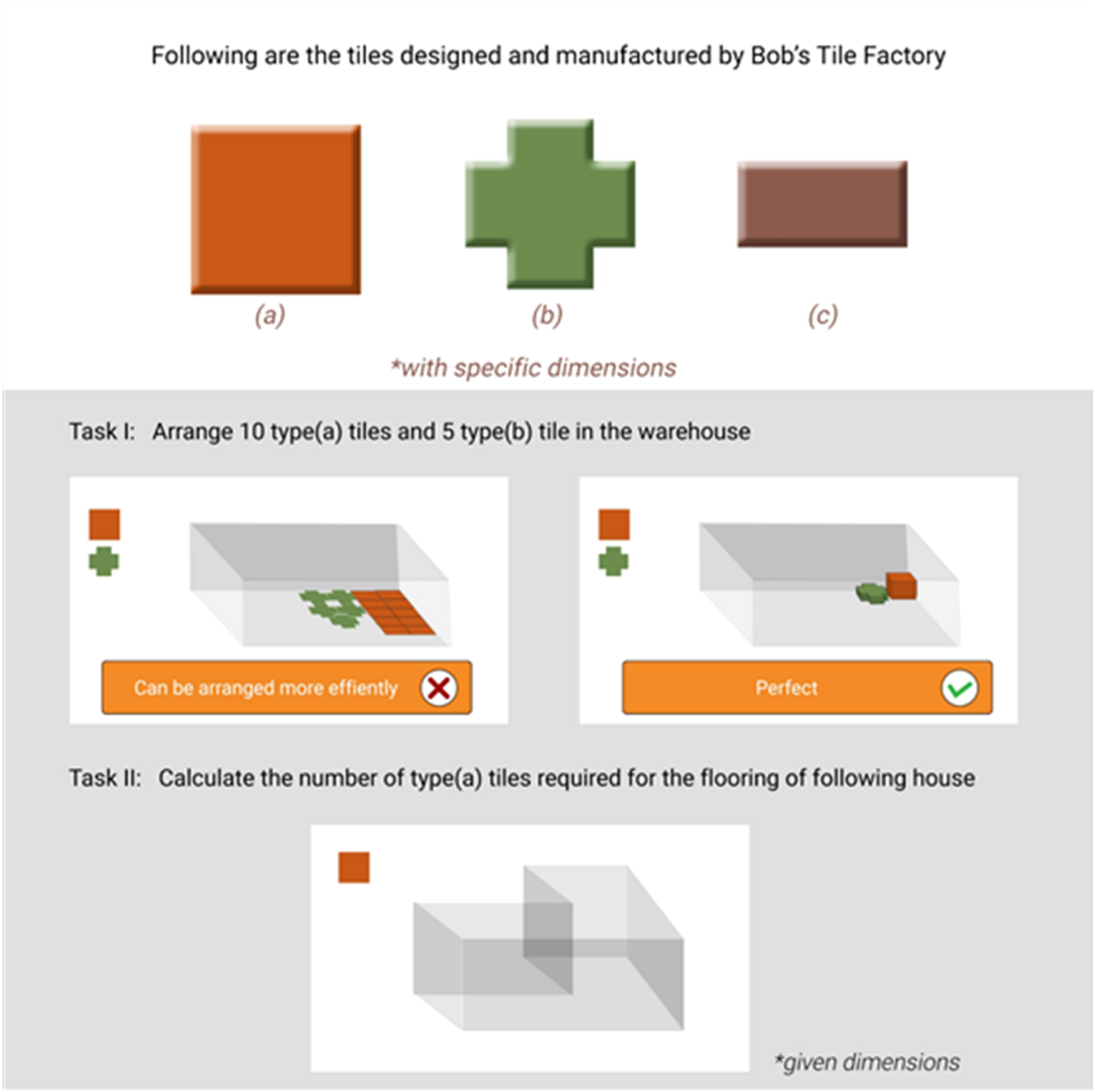
| #P12 | **Game Name: Bobs Tile Factory** | **Educational Topic:** Mensuration (Maths) |
|---|---|---|

**Description:** This is a video game for reinforcing the knowledge of mensuration, particularly, the calculation of area and perimeter. In the game, the player manages and runs a 'Floor Tile' making factory he inherited. The player uses informed choices about worker, material and time management to run and upgrade his factory. Apart from the player's game skills, his knowledge of applied mensuration comes handy in efficiently supplying his orders. This inspires learning and application of the mathematics while retaining the fun factor.

**Endogenous Elements:** Area and Perimeter of different shapes, Area with borders

**Medium:** Digital

**Sketch:**



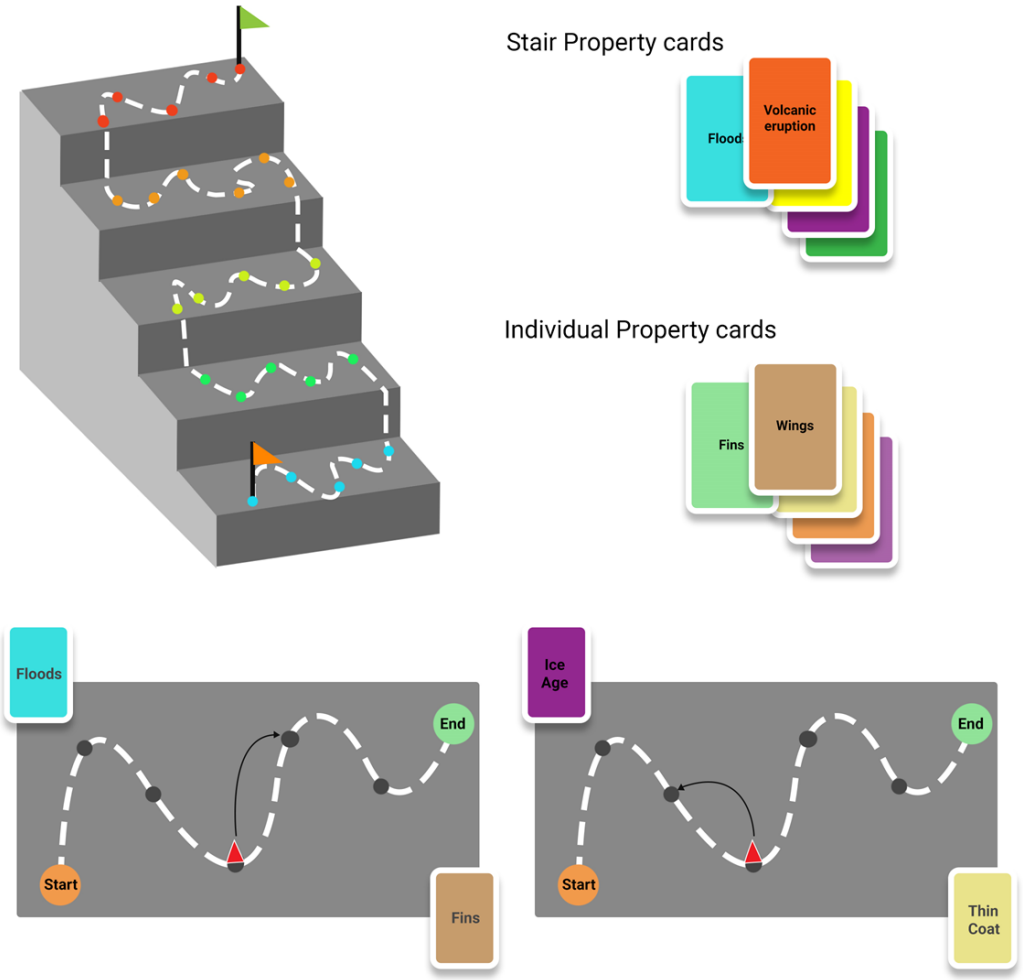
| #V12 | **Game Name: Speedvolve** | **Educational Topic:** Biodiversity (Environment Science) |
|---|---|---|

**Description:** Speedolve is a game for learning evolution in environment starting from water life to humans. 3 players play the game and they start at first stair and evolve into next and so on. Every stair has an individual board game. There will be 5 property cards at every stair indicating properties of the environment of that stair. There are also 5 property cards for species. Players randomly get one specie and one environment card but they can change it on next turn to match specie with favorable environment to evolve into a specie of next stage. It is a game of race, so once a player finds a match, he/she leaves the cards behind for other players and acquires the property cards for the next level. The player will evolve based on the properties and at the end of every stair. The first player to reach the end of the evolution cycle wins because as the saying goes, "survival of the fittest."

**Endogenous Elements:** Habitats, Species, Evolution

**Medium:** Board

**Sketch:**



| #V14 | Game Name: BRisk | Educational Topic: Conflict Resolution (Social) |
|---|---|---|

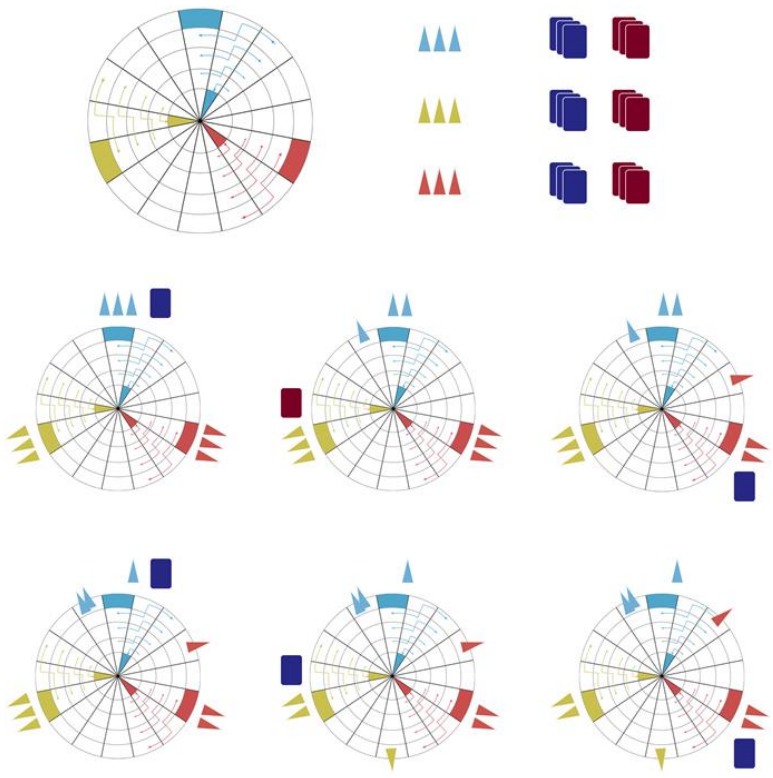
**Description:** The game evaluates individual's ability to perform in groups, by evaluating their collective decision making ability by resolving conflicts in order to reach a common goal. It also evaluates the overall risk taking behaviour of the team. The board has circular structure, which denotes a common starting and an ending point. There are 3 teams; each of them has 1 red and 1 blue card respectively Team has to take decision on color of card in their turn, in order to move ahead in the game. The team that completes the circle to reach the starting point again first wins the game. Conflict within the team is to decide what card to show, there can be a clash of ideas in order to select the color of the card. It needs a collective decision of the team. They resolve a conflict by coming to a collective decision.

In every round when the moderator asks the teams (all together) to show a card, they show either a blue or a red card. If all the teams show the blue card, they all move forward one-step. If one of the teams shows the red card and the other two teams show the blue card, the team with the red card moves 2 steps ahead, and the ones with the blue cards stay as it is. Moreover, there are more such combinations like that which determine if the team moves forward, stays at the same point, or moves backward in the game. There will be discussions only within the team and not between teams.

**Endogenous Elements:** Conflicts, Agreement

**Medium:** Board

**Sketch:**



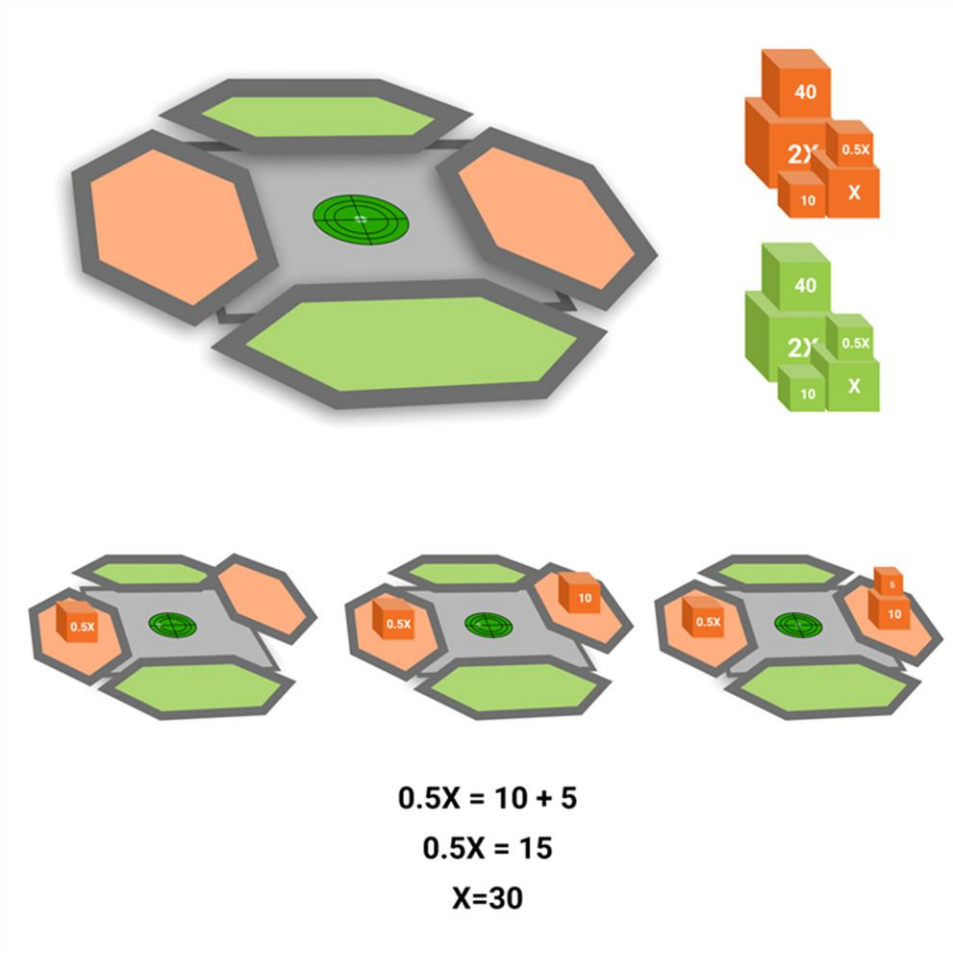
| #V21 | **Game Name: Balance** | **Educational Topic:** Equations (Maths) |
|---|---|---|

**Description:** Balance is a game for learning balancing of equations and solving them through two methods: 1. Trial and error 2. Solution method. The game is a physical object consisting of four moveable hexagons and a moving platform in between. Hexagons move as per the weight put on them, and the platform is the reference against which the balance shall be measure. Platform can be spirit level, digital display, and an audio device. Four players play as two teams. Each team has two players who use opposing sides and take turns. The partner puts a weight (can be called x or 2x etc) and the player has to put appropriate weights to balance that and find the value of x. The team also has to ruin the game of opponent team by passing weights that do not match in their turn.

**Endogenous Elements:** Balancing equations

**Medium:** Mechanical Device

**Sketch:**



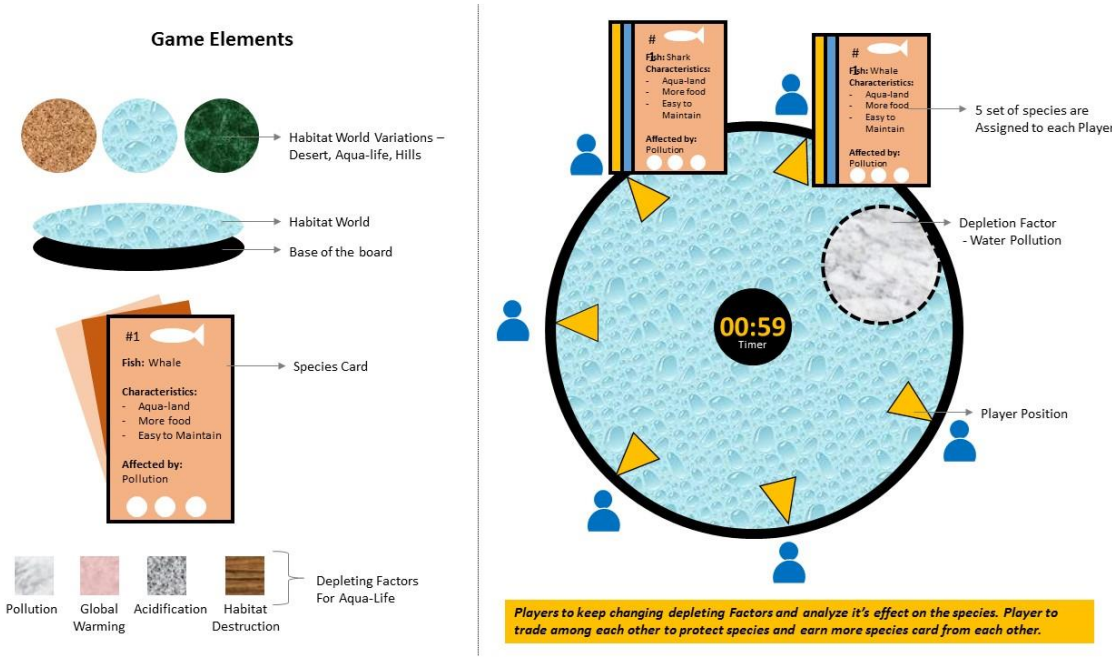
| #V22 | **Game Name: Hold On** | **Educational Topic:** Biodiversity (Environment Science) |
|---|---|---|

**Description:** Hold on is a board game concept based on giving players a chance to learn about various species, their attributes. Players collectively contribute to saving the planet from depleting factors while minimizing the rate at which species are becoming extinct. The focus of the game is to sustain all the species for a maximum amount of time. The player who saves the maximum number of species is the winner. To increase interaction between various players, each of the species has certain dependency on others for survival. A board with various habitats – Desert, Water, Hilly Region and Plains, where each player owns one habitat and has to acquire/cultivate species that survive there and pass species that do not survive. The habitat can deplete of resources and this is determined by spinning of wheel.

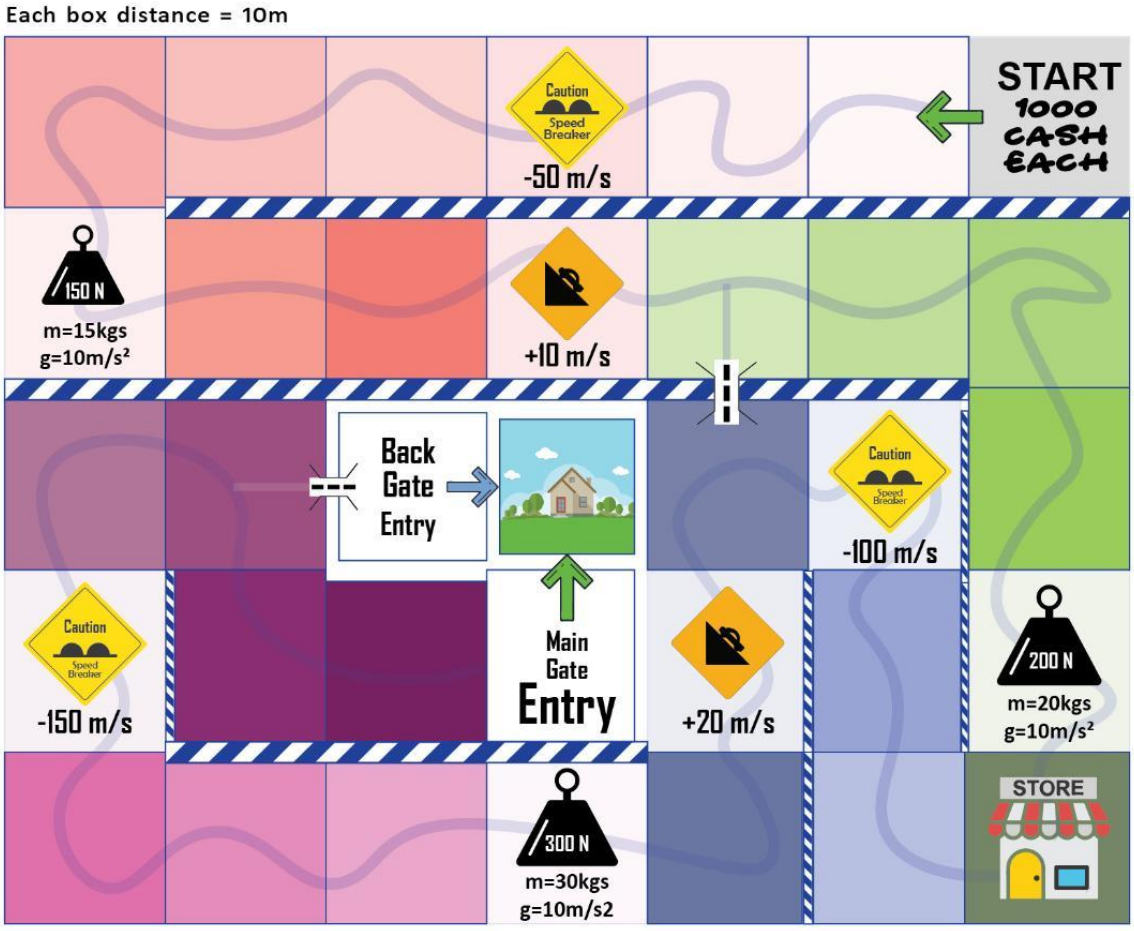
**Endogenous Elements:** Habitats, Species, Pollutants

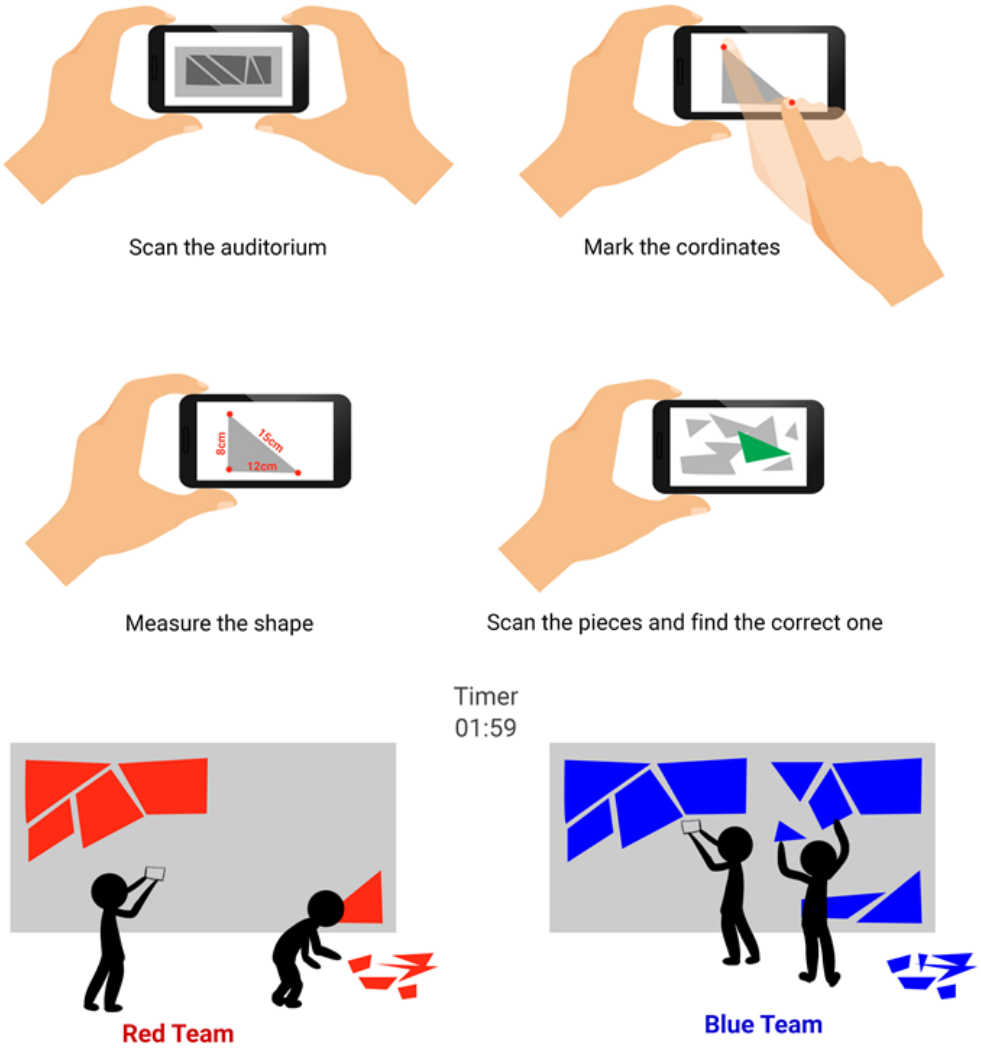
**Medium:** Board

**Sketch:**



| #V23 | **Game Name: LOM Race** | **Educational Topic:** Motion and Force (Physics) |
|---|---|---|
| **Description:** LoM race is a game for learning motion, force and work. 2-4 players can play the game. The board is subdivided into a matrix of squares and players have to move their token (i.e., a car) from start to end. On players turn, the cards would be used to combine speed, time etc., to move the car on the board. There are power cards and ramps on the board, which can increase the movement of the player. Obstacles and baggage can be used to slow the movement. The last player to reach the center (HOME) with maximum cash wins | | |
| **Endogenous Elements:** Force, Speed, Equations | | |
| **Medium:** Board | | |
| **Sketch:** | | |



| #V31 | **Game Name: Decorimeter** | **Educational Topic:** Mensuration (Maths) |
|---|---|---|
| **Description:** Decorimeter is a game to learn concept of area and perimeter. The context is to decorate school stage, which has pre-built stage scenarios (backgrounds) that can be filled by geometric shapes. Shapes are available to the players to fill in. Two teams of two members compete to decorate stage. Team members have to pick up shapes by measuring area and perimeter and fit on the background for the stage deco. The team that finishes maximum number of segments of the background first, wins. | | |
| **Endogenous Elements:** Area, Perimeters | | |
| **Medium:** Digital | | |
| **Sketch:**   | | |

| #V43 | **Game Name: Work It Out** | **Educational Topic:** Motion and Force (Physics) |
|---|---|---|

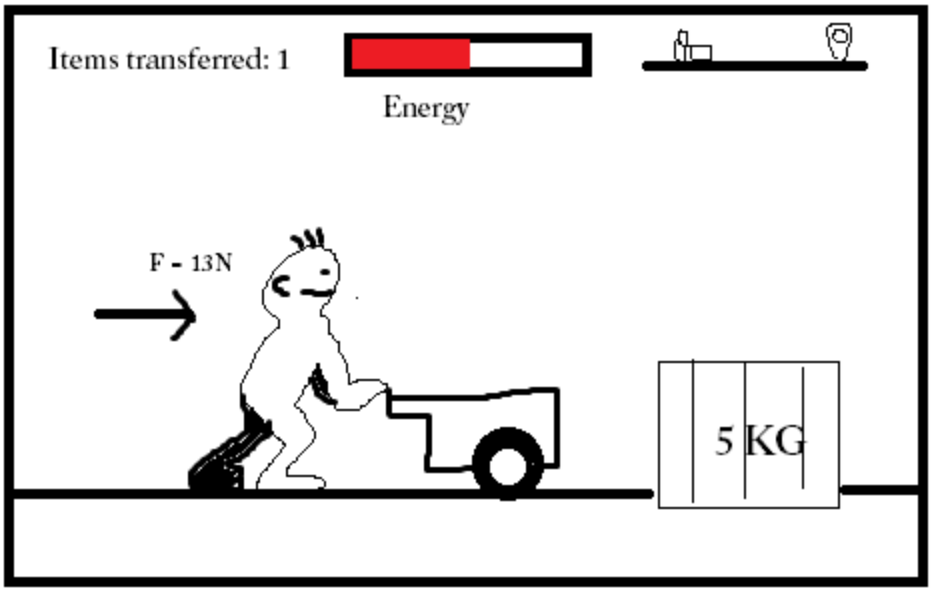
**Description:** A digital fun-interactive game intended to teach students on how mass, acceleration affects force. It also incorporates Newton's first law of motion. The imagery is similar to textbook equivalents, to provide the players with a better understanding of the concepts. The player plays as a person who is trying to transport weights from one point to another under a given time. Each round lasts around 4-5 minutes at most. The game starts when the player hits the play button. In the beginning, the player will have a trolley with its mass mentioned. The player's energy bar on the top left corner of the screen shows how much force he can exert. As he starts pushing the trolley, the energy bar slowly comes down.

However, as soon as the player sees a weight lying down, he would have to pick it up and load in the trolley, thereby effectively increasing the mass of the trolley further. Since the force applied by the person is not varying much, the acceleration decreases and is shown on screen. The player can increase his pushing force further, which in turn reduces his energy at the same rate. At the end of the allocated time, the total number of weights transported determines the score of the player. The following round will be for work done to lift up water from a well. The physics learning will be incorporated by on screen tips that tell the player how much he should increase the force for the water to be pulled up and likewise.

**Endogenous Elements:** Force, Mass, Acceleration

**Medium:** Digital

**Sketch:**



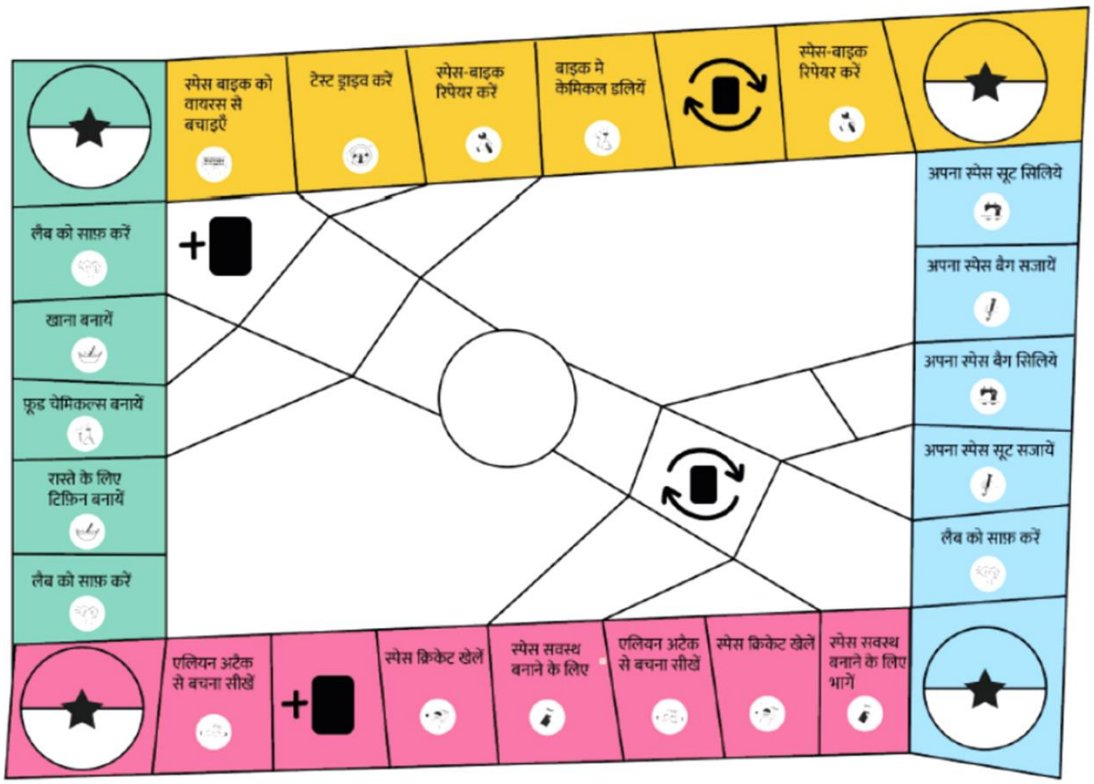
| #V44 | **Game Name: Space Equate** | **Educational Topic:** Gender Equality (Social) |
|---|---|---|

**Description:** Earthlings have landed on a new planet where they must earn star medals to be citizens of the new planet. To do this, players travel through different regions of the game board like the food lab, travel station, toy lab, and fitness station and solve tasks using their skill cards. The cards provoke players to work against gender biases so that they can move faster, with less effort. The team to win max medals wins.

**Endogenous Elements:** Tasks that are commonly seen through gender bias

**Medium:** Board

**Sketch:**



# End of Document