

Strategies for Endogenous Design of Educational Games

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ABSTRACT

Educational game designers strive to fulfill the promise of making learning fun. Games with endogenous design can fulfill this promise. In endogenous design, the gameplay emerges from the content, thus seamlessly integrating the act of playing with learning. However, a review of literature informs us of the lack of guidance on the endogenous design of educational games. There is a need to develop a framework which can aid designers achieve endogenous design.

In this paper, we propose strategies for the endogenous design of educational games. We conduct in-situ studies using think-aloud protocol analysis to extract the tacit knowledge that designers discreetly use in practice. We synthesize the extracted knowledge into concise design strategies. The identification of these design strategies is a significant step towards building a framework for endogenous design of educational games.

Keywords

Endogenous Design, Design Strategies, Educational Games

INTRODUCTION

Critics often use the term ‘chocolate-coated broccoli’ to describe the character of educational games. Coating educational content with incoherent gameplay is a common pitfall in the design of educational games. Design pitfalls lead to games that are neither fun nor educational. The existence of such pitfalls is not surprising because designing educational games that fulfill the seemingly contradictory functions of fun and seriousness is challenging (Flanagan, 2009). Seamless integration of content with gameplay is vital to addressing this challenge. It has been established that games with seamless integration (also termed as endogenous design) are effective as they harness the intrinsic motivation of games for delivering learning (Habgood et al. 2011). While the need for endogenous design is established, the strategies to achieve such designs are not (Ke, 2016). The purpose of our work is discovering strategies for endogenous design. In the present work, we do not focus on either reconfirming or challenging whether endogenous designs are indeed effective.

Endogenous Design

The discussion on endogenous design can be traced to Malone (1980), who introduced the terms intrinsic and extrinsic fantasy. These terms indicate the mode of integration of educational content in the games' fantasy world. Malone proposed that 'endogenous fantasy', in which content is intrinsically related to fantasy, produces better learning. Recently, Habgood et al. (2005) have argued that content integration need not be restricted to the fantasy element in the game. These authors suggest the need to deliver learning through various parts of the game that are fun to play while relying on the flow experience. Squire (2006) makes a distinction between learning via exogenous and endogenous games to indicate the advantage of endogenous design. He argues that learning in exogenous games is through memorization of facts while in endogenous game it is through doing or experimenting using game mechanics. Similarly, instruction in exogenous games is through transmission whereas in endogenous games it is through construction and making meanings from the act of playing.

While endogenous integration of content and gameplay is one approach to endogenous design, endogenous generation of gameplay is another. Kafai (2001) proposes a constructionist approach in which designers find interesting elements within the content and use these to create games. This is different from an 'instructionist' approach where learning content is embedded in the gameplay. Endogenous game design, therefore, is defined as the seamless coexistence of content in the game system, achieved either by integration of content into game elements or generation of game elements from content elements.

Inadequacy of Design Strategies

Research on educational games has predominantly focused on evaluation rather than the synthesis of games. Within the literature on synthesis, the often-cited Game Object Model (Amory, 2007) and the Learning Mechanics to Game Mechanics (LM-GM) mapping model (Arnab et al. 2015) focus on the integration of instructional elements into game systems. Prensky (2001) proposed a mapping of suitable game styles with various types of learning, for example, card games for learning facts, role-play game for learning behaviors, and so on. These macro-mapping frameworks do not address the question: "how does a designer integrate elements of the content in a game?" Bellotti et al. (2010) concur with our view. They observe that despite the abundance of literature on educational games, very few papers provide specific strategies through which a topic is "translated" into a game.

Amongst the few papers that guide our research, includes the work of Isbister et. al. (2010). The authors interviewed wide range of successful design practitioners to identify best practices for designing learning games. Their participants acknowledged that embedding the content deep into mechanics yields best results. We borrow the approach to study the practitioners but focus more on specific strategies. In the space of integration methods, we find an inquiry based approach for connecting learning objectives to gameplay (Hall et al. 2014). These authors provide a set of questions that designers need to answer to complete the mapping between real world and game world. Likewise, Deterding (2015) proposes a method for 'gameful design' consisting of design steps, in the context of gamification. His design framework offers useful directions for the synthesis of our research. A literature review by Ke (2016) is a valuable resource for discerning the themes of intrinsic integration of learning in games. In her review, she gleans five broad themes of integration, which include the purpose of integration, modes of integration, blended learning spaces contrived by mechanics, and learning support. However, she also underscores the lack of specific design strategies for learning-game integration and claims, "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".

Our Research

The objective of our research is to generate knowledge in the form of design strategies for endogenous design of educational games. We refer to design strategies as specific methods, working principles, tactics, techniques, and design steps in the design process that designers can use towards achieving their design goals (Hubka, 1983).

A design workshop conducted by us provided an early indication of the range of design strategies, which we could discover. In this workshop, we invited design students to design games on selected educational topics. We discovered rudimentary strategies for creating endogenous design. These strategies dealt with identifying elements from the content, and their translation onto game elements using game mechanics. The insights from this workshop have been published in an earlier paper (Athavale et. al. 2019).

The canvas of educational games being vast, the scope of our research is restricted to topics from middle school textbooks (sixth grade to ninth grade). The choice of this segment is for practical reasons such as a) designers do not need expert help to understand these topics and, b) the selected age group is comfortable in playing games. Although it is possible to generalize and extend the results beyond this segment, for this paper we focus on specific age groups and topics.

Our approach for advancing knowledge on design strategies is through the study of design practices. According to Cross (1997), design knowledge can be generated in three ways: the study of design artifacts, practices, and abilities. Knowledge of design strategies is best acquired through the study of design practice in-situ. Such a setting allows the researcher to understand how designers apply tacit knowledge for taking design decisions. Mateas (2005) further reinforces this view by claiming that studying the act of designing games offers an alternative method for researching and understanding game design, beyond what can be understood by playing and studying existing games alone. We confined our studies up to the conceptualization stage and did not focus on prototyping and playtesting. Study of conceptualization suffices for the identification of strategies.

In this paper, we discuss our research methodology, studies, and observations and the organization of emergent strategies.

RESEARCH METHODOLOGY

We selected Design Based Research (DBR) as a methodological framework for studying design practices. This is a pragmatic philosophical approach, in which the value of a theory lies in its ability to produce practical applications (Barab et al. 2004). While DBR serves as a broader research framework, specific methods are required to conduct studies. We selected think aloud protocol analysis as a method for studying designers' in-situ. Protocol analysis is commensurable with DBR, as both do not need a prior hypothesis, and the theory emerges from the participants' knowledge.

While several methods are available for in-situ studies, protocol analysis is a rigorous method for eliciting verbal reports of "thought sequences" and is widely considered as a valid source for acquiring data on the thinking process (Ericsson et al. 1980). It is considered a self-validating method due to the natural process of induction and constant comparison of data between participants. As a relevant case, Motte et al. (2004) used it to study design strategies and tactics employed by participants during an engineering design process. Though protocol analysis is an effort-intensive technique, it is appropriate when rich qualitative data about few individuals is needed rather than quantitative data about populations (Kuipers et al. 1984).

Protocol Experiment Planning

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 analyzed post facto. We planned one session per study, with each session scheduled for approximately three hours. This duration was chosen considering that shorter duration might lead to incomplete concepts and longer durations may lead to participant fatigue. We did not plan multiple sessions for the same participant, because a part of the design thought process between the sessions could not have been captured. During the session, the participant was expected to conceptualize a game, sketch the concept, and document it. The participant was not expected to develop a playable prototype.

The planning consisted of pre-session, in-session, and post-session activities for the researcher and participant. Pre-session activities for the researcher included preparation of design briefs, development of evaluation rubrics, and obtaining participants' consent. The design briefs consisted of design topic (a specific chapter from middle school textbook), learning goals, references and expected outcomes. The rubrics were developed to evaluate the completeness and 'endogenousness' or the extent of endogenous elements used. As part of preparation, a note on the concept and nature of endogenous design was shared with the participants in advance, along with examples of endogenous and exogenous designs. Participants were requested to bring as many elements from content into gameplay as possible.

In-session activities included a practice run of the think-aloud method to familiarize the participant. We intended to capture the thought process from the point the participant started reading the topic. Hence, design briefs were shared with the participant at the beginning of the session and not earlier. The researcher guided the participant to break the session into four segments: understanding the topic, divergent thinking, convergent thinking, and finalizing/documenting the game concept. This breakdown was a suggestion and was not strictly enforced. The researcher took notes wherever the participants reasoning for their decisions were inadequately articulated. At the end of the session, an interview was conducted to fill these gaps.

Post-session activities included an evaluation of the concept. We empaneled independent reviewers and provided them with evaluation rubrics to assess the completeness of the game concept and the extent of endogenous nature of the design. Concepts, which were either incomplete or highly exogenous, would be excluded from the analysis.

Pilot Studies

Two pilot studies were conducted to validate the choice of research methods and adequacy of planning. The pilot studies confirmed that the selected methods were suitable for identifying strategies (Athavale et.al. 2018).

Research Design

For collecting the required data, we planned twelve design sessions (S1 to S12) as shown in row 1 of Figure 1. Twelve participants (P1 to P12) were asked to participate in one design session each. Thus, P1 participates in session S1, P2 in S2 and so on, which can be inferred from row 2 of Figure 1.

Six educational topics (T1 to T6) were chosen for the game design task. This list was created through a survey of school-teachers. Teachers were asked to list topics that would help students most if they were converted into games. These topics were then classified based on the type of content (C1 factual, C2 conceptual, and C3 procedural) using the Krathwohl content classification scheme (Anderson et al. 2001). To remove topic specific biases, two topics for each type of content were selected. The selection

of topics across multiple types of content ensures that our research claims are not restricted to a certain content type. Each topic was assigned to two participants, which can be inferred from row 3 in Figure 1, to negate participant specific biases.

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 1: Research design

Main Studies

Though we planned for twelve studies, we could stop after ten studies. Nine of the ten concepts generated had passed the evaluation criteria for further analysis. Protocol analysis method suggests a constant comparison of data across participants and the induction process can stop when the codes saturate. We encountered saturation after nine studies and our results are based on the same. We however acknowledge that this saturation might be local maxima, attributed to the fact that the participants belonged to the same cultural backgrounds and within the accessible circles of the researchers. Participants from varied nationalities, different cultural backgrounds may bring forth divergent cases. Additional studies may be needed in future to extend our findings and validate our claims in universal context.

Designers with varied experience ranging from those who recently studied game design at school to those who have worked in professional game design studios, as well as amateur designers were recruited for participation. Participants had varied educational backgrounds and came from diverse geographical locations. The gender distribution was three females and seven males. The data from these nine main studies and two pilot studies were included in the analysis. It is established that prior experience has a correlation with the participants' design approach (Ozkan et al. 2013) and hence the variation. Novices tend to be original in their approach, whereas experts are likely to establish structural similarity or compliance with existing systems unless specifically asked to be innovative.

Method of Analysis

Data collected from the studies was transcribed in the first pass. In the second pass, we identified various facets of the data and listed prominent entities and their relationships. We also created an Entity Relationship (ER) diagram to visualize the facets at a glance. In the third pass, we started the process of coding. A tool was used to attach codes to various segments of each recording. 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). In inductive coding, codes are not pre-defined but they emerge from the data. These codes are expected to represent the phenomena of interest. We, therefore, coded tactics, methods, and techniques that designers used during several design steps.

The identified codes were tabulated across participants for the purpose of aggregation, categorization, and comparison. Aggregation aided in the creation of a superset of codes, and categorization aided in the segregation of codes into meaningful groups. Comparison of codes between participants helped in identifying missing data, along with the differences in the designers' approach. To avoid biases in coding and categorization, a panel of two independent researchers was created. Tabulated data was shared with this panel for their interpretation.

OBSERVATIONS

In this section, we describe the observations from the collected data.

Facets of Data

Through the entity relationship diagram as indicated in Figure 2, we detected four logical groups within the collected data. The first group consists of participant and their background. Participants use their abilities and inspirations to perform design activities. The second group comprises of activities and strategies. These activities include ideation, study of content, transformations, evaluations, seeking alternatives, and revisions. Part of the activities are similar to the generic micro-strategies for design suggested by Gero et al. (1998) but others such as transformation are specific to game design. We noted that participants employed various strategies for performing content extraction, translation, integration and ideation activities.

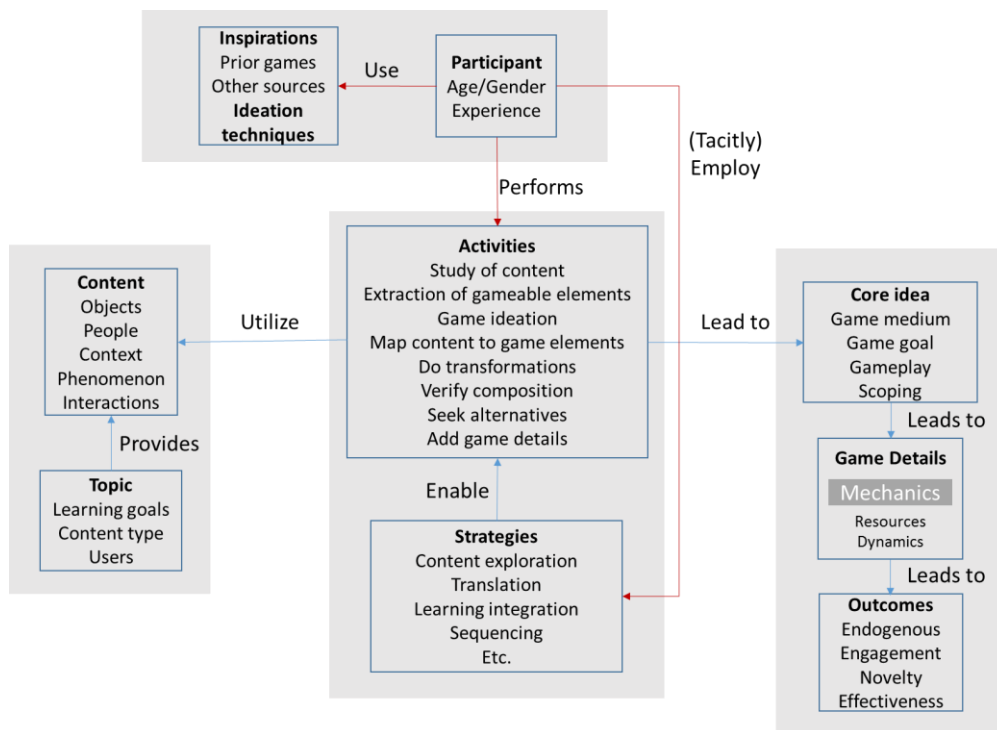


Figure 2: Entities and Relationships

The third group comprises entities related to the topic and content. The breakup of content into sub-entities has not been represented in Figure 2. The fourth group involves entities related to game system, such as the core game idea, core and opposition mechanics, and other game details. Mechanics are highlighted since they are central to the emergence of game design.

Identified Codes

A section of the tabulation of identified codes is shown in Figure 3. In this figure, each column represents data of one participant. Each row represents a code observed from one or more of the participants. The cells represent values (data) for each participant. Inputs from the independent coding panel helped refine our codes and categories, as we finalised approximately 45 codes in six categories/groups. We named the six groups as Exploration (of content), Core ideation, Translation, Learning integration, Game detailing, and Meta-strategies. The salient strategies observed in each category are described in the following subsection.

	Main Study	1	2	4	n
	Participant	P1 (M 30)	P2 (F 26)	P4 (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 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/contraction, 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: Tabulation of Codes

Categories of Strategies

Content Exploration: We observed four different methods for content exploration. The first method is a full content walkthrough. In this method of content exploration, designers made a list of various elements in the content. During the full walkthrough, designers look at various facets of the content, such as spaces, layouts, objects and their properties, actors and their actions, situations, and events. Designers also study interactions between actors as well as interactions between actors and objects.

The second method explores content from specific perspectives, such as human-centered, object-centered, and situation-centered perspectives. For example, in the human-centered perspective designers identify the goals and behaviors of actors in a context. The context is any scenario manifested by elements of the content. In the topic 'Heat', an example of the context is a steel factory where goals of human actors were identified as 'heating the object' to make it move faster on the assembly line, and cooling the opponents object to slow its movement.

In the third method, designers look for striking features and the highlights of the content. This includes searching for movements such as the flow of current in ‘electric current’ topic or opposite pairs such as heat and cold in ‘Heat’ topic. Alternatively, designers also look at elements that are easily accessible without digging deep into the content. This method provides a quick turnaround but tends to have a lower coverage of content.

Core Ideation: Designers 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). Novel gameplay ideas tend to emerge later when specific translation methods are used. Designers go back to modify and restart the core idea at various stages in the design process. The core idea and hence the game design evolves gradually through an iterative process.

Designers repeatedly validate how their design decisions affect scope, scalability, endogenousness, learning delivery, fun, and complexity. We observed that the quality of endogenousness is not binary. Designers create endogenous designs of varying degrees. For example, in the ‘fundamental rights’ game, the feature of, “rights cards cannot be destroyed without special powers” was an endogenous element in otherwise exogenous gameplay of racing. However, the verdict on ‘what level of endogenous design is better’ is not obvious and requires further research.

Decisions concerning the scope and coverage of the content in the game are taken at various points. Some designers determine the scope of learning in the beginning, whereas others defer until the core game idea is decided. If the content has recurring patterns or examples, as in the case of game on ‘chemical reactions’, designers cater to only one case and decide that rest of the cases will follow the template of the first case.

Content to game translation: After deciding the initial core idea, designers look for methods to translate content elements to game elements. Several layers of translation are observed. The first layer is for decisions regarding the game world, which includes the plot, theme, narrative, and the setting. Since these elements have some overlap, we observed that such decisions are taken in concurrence with each other. Inexperienced designers create replicas of the real world (simulation) at the first instance since they are easier to synthesize. Later, they would add fantasy elements to the simulation. Designers with digital game design experience tend to start by creating a fantasy world with a story, characters, and puzzles. Designers having background in tabletop games focus on objects and properties, and begin with a physical representation.

The next layer of translation is choosing an anchor element. The anchor element is the central element from the content chosen by the designers for translation. If the anchor element is a ‘resource’, then real world objects are transformed to game resources. For example, in ‘rocks and soil’ topic of geography, rocks become resources and then interactions such as acquiring, trading, using them to construct, attack etc. come to fore. Our data indicates that mechanics is the most common anchor. To come up with mechanics, designers enlist actions that humans can perform with elements in the content. In a few cases, designers start with an opposition mechanic when it is more prominent in the content. When designers are unable to synthesize an endogenous game mechanic, they tend to choose a fallback mechanic, which does not emerge from the content. In the rocks game, using ‘race’ is an example of an exogenous mechanic.

In the third layer, designers work on the system of mechanics. The core mechanic, opposition mechanics, and satellite mechanics form this system (Fabricatore, 2007). Designers spend significant effort in designing the system of mechanics. This is natural, because amongst the three key components Mechanics-Dynamics-Aesthetics (MDA) of the game system, designers directly control mechanics design (Hunicke et al. 2004). Our studies suggest that designers often struggle to identify a suitable opposition mechanic when it is not prominent in the content. In such cases, designers use exogenous opposition mechanics. However, few designers also use this 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 designer came up with a novel idea of holes (shapes that represent holes) as an opposition mechanic. Table 1 presents examples of how the mechanics emerged from content elements.

Topic	Striking Properties	Emergent 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	

Table 1: Content to Mechanic Translations

Learning Integration: While content translation strategies enable integration of content in the gameplay, designers take additional efforts for integrating learning delivery such as a) deciding the objective, whether they will address knowledge acquisition, application, or both, b) choosing the learning delivery mode, and c) designing elements of the game to deliver learning. The learning delivery modes include visual elements, mechanics, information, player choices and others.

In our studies, we find a trend similar to that reported by Ke (2016), i.e., designers focus more on prior-knowledge activation as compared to novel knowledge acquisition. Designers found it difficult to design games for novel knowledge acquisition. They took the route of introducing concepts through a scaffold such as cues, and asking players to apply them in game.

Game Detailing: In the game detailing stage, designers revisit and elaborate earlier design decisions and finish the design of remaining components of the game. The detailing stage predominantly included a) defining rules for starting, progressing, ending and scoring in the game, b) checking and introducing elements for fun such as curiosity hooks, chance, entitlements, traps etc., and c) introducing events and rules that influence game dynamics. We found that designers take detailing decisions using knowledge of prior games as well as clues available in the content elements. In the

‘fundamental rights’ game, the designer took a cue from prior games and created a hexagonal board with a physical terrain that restricts player movement. A layout inspired by the content could have led to an alternative board depicting the political terrain of a war-affected country.

Meta-strategies: Meta-strategies deal with approach for selection and sequence of various strategies used by the designers. We observed the sequence of activities, and found two approaches, first where designers get fixated to a gameplay idea as soon as the topic is assigned to them, and second where they spend time in exploring the content before generating gameplay. Some designers take a conservative approach and select known gameplay whereas others wait and work for the gameplay to emerge. Each of these choices affects the quality of design. Known gameplays naturally lead to lesser novelty and are less likely to create endogenous design.

Though every designer follows a different sequence of performing activities, we discovered one prominent macro sequence. Figure 4 depicts the typical flow and evolution of the core concept. Designers begin by reading the problem statement. After this stage, designers either start exploring the content in detail or think of a game idea. Either of these paths led to the first version (v1) of the concept. The concept is gradually enriched through different stages of the design such as translation, integration, and detailing. The flow through the stages is iterative.

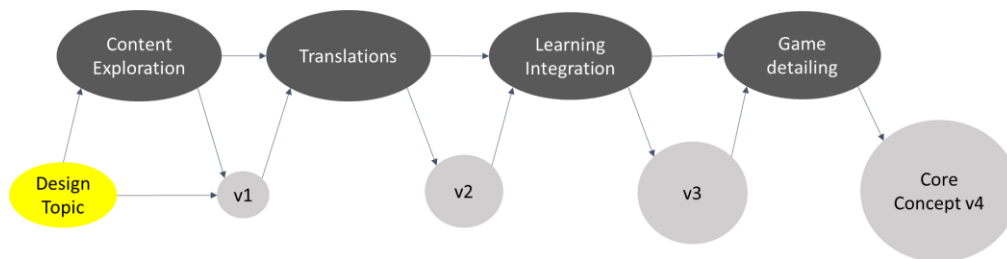


Figure 4: Typical Sequence of Concept Evolution

SHAPE OF STRATEGIES

We have identified the game design strategies, their groupings, and a prominent sequence as part of the observations. In this section, we discuss the proposed system of strategies. The system is developed through a) generalization of findings, b) theoretical extensions of the set of strategies using interpolation, extrapolation, and blending and c) creating logical sub groups of discovered strategies within the previous identified groups. In the following subsections, we describe strategies in each group and indicate how designers could use them.

Content Exploration Strategies

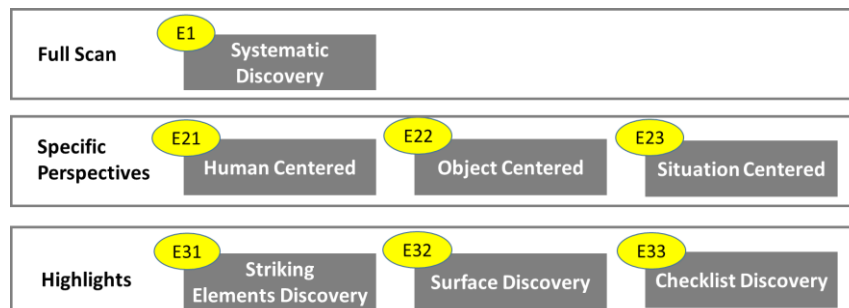


Figure 5: Content Exploration Strategies

Klopfer et al. (2009) advised designers to ‘seek fundamentally game-like elements in the content’ to achieve endogenous design. The content exploration strategies shown in Figure 5 enable designers to do that.

E1 is a systematic exploration strategy, which aids the designers to go through the content systematically. This includes exploring multiple dimensions and noting elements such as a) actors and their goals, actions, interactions, behaviors, b) spaces including layouts and conditions, example, light/darkness, c) temporality and events, example, earthquakes in ‘rocks and soil’ topic, d) objects and their properties and e) intersections between actors, objects, space, and time.

Strategies E21 to E23 are based on specific perspectives. The human-centered perspective helps designers to investigate and understand the role of humans in the context. The object-centered perspective helps focus on objects and the actions that can be performed on them. The situation-centered perspective, aids designers to focus on situations in the context. These strategies enable designers to extract useful content elements from multiple perspectives.

Strategies E31 to E33 are quick turnaround techniques. E31, aids designers in search for striking elements and peculiarities in the content. Peculiarities are found in contest-candidates, happenings, and patterns. Contest-candidates are elements that can be pitched against each other such as heat versus cold. ‘Happenings’ are occurrences, incidents, transitions, movements that are observed in the context, and patterns are elements and structures that repeat. Another alternative to identify striking elements is finding out something inherently boring in the content so that it can be inverted. Even though systematic discovery E1 provides better coverage of content, E31 plays a significant role in translation to gameplay.

Strategy E32, informs designers to pick up superficially visible elements rather than scan the entire content. This strategy is fraught with the danger of missing key aspects of the content, but experts can use it for a quick turnaround. Finally, we introduce E33 as a new strategy where designers can use a discovery checklist. The checklist directs the designers to search the content for a) possible actions of humans, b) things that change and c) key resources that can be manipulated. This strategy is better than E32 in terms of searching gameable elements.

Core Ideation Strategies

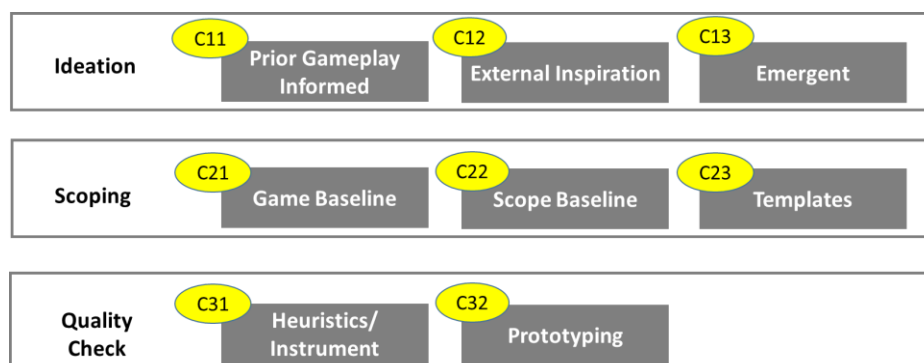


Figure 6: Core Ideation Strategies

Core ideation strategies shown in Figure 6 are directed at creating the core concept of the game, deciding scope, and performing quality checks.

There are three prominent strategies to develop the core concept. These are labeled C11 to C13. Strategy C11 is the most common, which helps designers to begin with known gameplay ideas and map content elements onto the gameplay. C11, however, does not yield highly endogenous design. C12 is based on the use of external inspirations such as movies, nature, and so on. C13 is a strategy where the core concept emerges from the content. The use of C13 usually leads to endogenous design.

The coverage of content in the game varies based on the design. C21 to C23 are different strategies to determine the extent of learning content to be incorporated in the game. In game-baseline strategy C21, the designers would finalize the game design and then choose content that can be accommodated within the design, whereas in scope-baseline strategy C22, the designers finalize the scope and extend the design to incorporate the decided scope. Strategy C23 is useful for creating a scalable design, specifically in the case of digital games. This strategy aids designer to create templates and address recurring patterns and scenarios in the content. A design template is a blueprint of a game scenario and typifies most similar scenarios.

Strategies C31 to C32 are used to check game quality. The quality is checked using heuristics, instruments (for measuring engagement, effectiveness etc.), and through playtesting of prototypes.

Translation Strategies

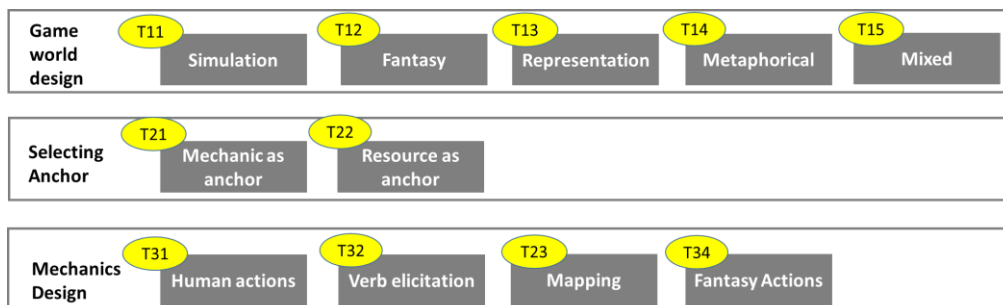


Figure 7: Translation Strategies

Translation of extracted content to game elements is vital to creation of endogenous design. Organization of Translation strategies are shown in Figure 7.

Content to game translation typically begins with the design of game world (strategy set labeled T11 to T15) followed by finding anchor elements for translation (set T21 and T22), and design of mechanics (set T31 to T35). There are five strategies T11 to T15 to design the game world. These include choices for creating a simulation world, a fantasy world, an object representation, a metaphorical representation, or a combination of these. Ke (2016), has previously identified three of these, conceptual representation, simulation, and contextualization as game-learning integration modes. Conceptual representation is the embodiment of concepts using an object and its properties to create a representation in the game world. Contextualization is the act of creation creating a fantasy world.

In the metaphorical world strategy, content elements from the real world are transformed into alternate representations. These alternate representations include personification of concepts, for example, heat as a villain, cold as a savior. In the mixed world strategy, the elements of simulation, fantasy or object representation are fused. For example, in the geography game, rocks were assigned both real and imaginary properties. Examples of imaginary properties are the ability of rocks to stick together or become transparent. The game goals are decided along with the decision of the game

world. The goals extracted from the content are translated to the game, for example, carrying material to its destination using heat and cold. Alternatively, fantasy goals are chosen to match the selected game world, for example, killing a monster using heat.

Strategies T21 and T22 support the selection of an anchor element for translation. The anchor element is a standout element in the content. It is a central element considered for translation, and the remaining game elements are designed around this anchor. The examples for anchor elements are a) human actions, which are translated into mechanics or b) an object, which is translated into a resource. The anchor element can be an opposition mechanic as well.

There are five strategies T31 to T34 for translating content elements to game mechanics. T31 strategy is used to translate human actions identified in the content exploration. This includes spaces that afford movement, objects that afford manipulation, and interactions between people that afford exchange of information. If the actions afforded by these elements are not obvious, then strategy T32 of ‘verb elicitation’ is an option. Verb elicitation is similar to the use of verb cards in the VNA method of Kultima et al. (2008). Different verbs are associated with objects, spaces, and actors in the content to generate new mechanics.

The strategy T33 involves mapping known mechanics such as race, collect, solve etc. to objects, spaces, and actors in the content. Designers can refer to a library of mechanics (Jarvinen, 2008) to get access to a larger set of prevalent mechanics. However, applying external known mechanics to content elements may not result in an endogenous design. In strategy T34, imaginary actions or manipulations are associated with objects, spaces, and actors. The strategies for translation of mechanics are explained further using an example. In the geography topic ‘rocks and soil’, we discuss how the strategies help identify mechanics that can be associated with the object ‘rock’. Using T31, the actions possible on the object rock are gather, build, throw, break etc. Using T32, other verbs such as trade, hide, and carve and so on are associated with the rocks. T33 will lead the designers to think of collecting rocks on the run, and racing to the destination. T34 enables the designers to think of imposing imaginary actions such as sticking rocks together, magnetic repulsion between rocks, floating rocks etc. link

Opposition mechanics are determined using exploration strategy E31, through identifying contest-candidates, constraints, restrictive forces, and obstructions to the flow in the content. Opposition mechanics can also be determined by finding opposite verbs to the core mechanics. The core and opposition mechanics are not necessarily designed simultaneously; therefore, it is possible to have one mechanic to be more endogenous than the other.

Learning Integration Strategies

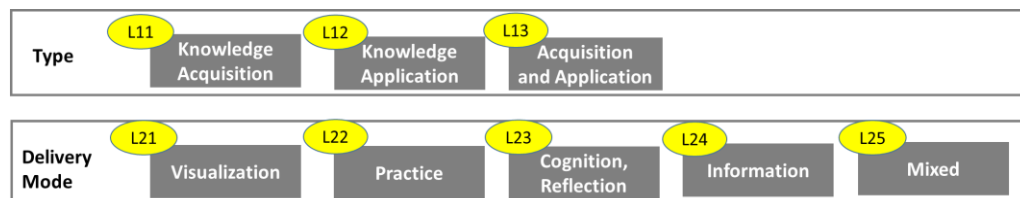


Figure 8: Learning Integration Strategies

Learning Integration strategies shown in figure 8, aid designers in deciding how learning is delivered through the game. Strategies L11 to L13 guide designers in orienting the design for player’s new knowledge acquisition, prior knowledge application or both. Choosing strategy L11 helps designers structure the design towards

new knowledge acquisition. The structures for delivering conceptual, procedural, and factual knowledge are different. In conceptual knowledge delivery, designers make use of examples. For example, in the ‘electric current’ topic, the example of marbles sliding on the slide can be used to explain the concept of current. Factual knowledge delivery involves making the information prominent using information cards or snippets. In the game of ‘fundamental rights’, the explanation of each right is available on the cards. Procedural knowledge delivery is through repetition of steps of the procedure. For example, in the ‘mensuration’ game, players can be required to calculate areas and perimeters on every move. Delivering conceptual knowledge through games is more difficult than factual or procedural knowledge.

The strategy L12 leads designers to orient the design towards knowledge application. In games oriented towards knowledge application, the players are expected to have prior knowledge of the topic. This prior knowledge is applied to solving problems and making decisions to move forward in the game. For example, in ‘fundamental rights game’, players are expected to know the rights a priori and use them to handle various situations in the game. L13 is a combination of L11 and L12 strategy where the game is designed for both knowledge acquisition and subsequent application.

Strategies L21 to 25 describe the learning delivery modes. Different game elements afford different kinds of delivery modes. The Game world delivers learning through visualizations, mechanics through repetition and strategic thinking, and cues and scores through information. Designers need to choose one or more of the game elements to deliver intended learning.

Detailing Strategies

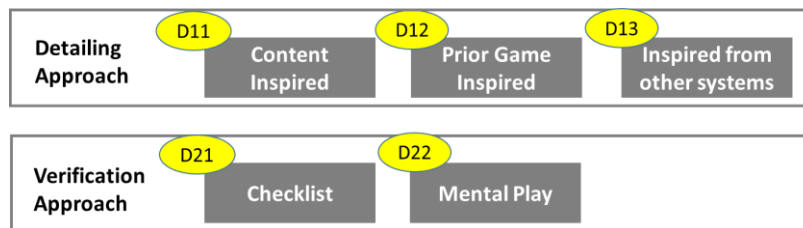


Figure 9: Detailing Strategies

The core game idea, the game world, and initial elements of the game system are generated during the core ideation and translation stages. The identified elements are elaborated and remaining elements are decided in this stage. Game detailing strategies aid designers in completing the design of various components of the game system. Figure 9 presents three strategies for detailing game elements. Strategy D11 uses elements from the content to complete the remaining details, whereas D12 refers to prior game knowledge for the same. In strategy D13, designers take inspiration from non-game systems, such as the use of a pay-off matrix to balance the main and opposition mechanics. Contained within these broad categories are specific techniques for designing various elements.

Strategies D21 and D22 aid designers in checking the completeness of the game. In strategy D21, designers use a checklist of game elements. This checklist can be derived from existing game design frameworks (Athavale et. al. 2017). Strategy D22 is useful for verification of game dynamics. Here, the designer needs to play the game mentally to identify loopholes in the design. Designers need to take special care to check the existence of fun elements in the game, and if missing, introduce elements such as chance, surprise, time limits etc., to enhance the game experience.

Meta-strategies

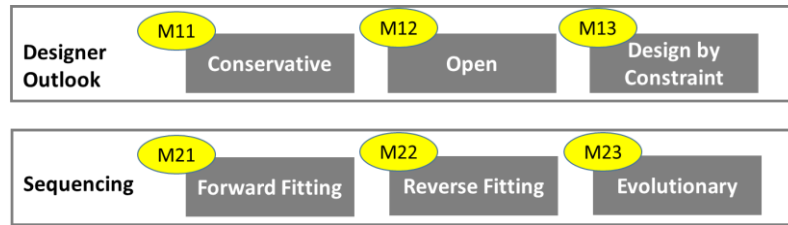


Figure 10: Meta Strategies

Meta strategies shown in Figure 10, guide designers in the overall sequencing and ideation of the game design. These strategies do not necessarily aid to endogenous design. M11 to M13 strategies guide the designers' outlook. M11 is a conservative strategy wherein designers seek low-risk options such as using known gameplays. This leads to low novelty and may have low endogenousness. M12 strategy champions a more open and exploratory approach where designers can attempt ideation using content elements. M13 is a strategy where designers impose constraints on the number of features, time spent on ideation, complexity etc. to finish the concept in time bound manner.

M21 to M23 are the sequencing strategies. M21 is a forward fitting strategy in which designers need to start with content and strive to generate the gameplay from the content. M22 is a reverse fitting strategy where designers begin with a gameplay and then fit content elements in it. M21 and M22 are used in conjunction with core ideation strategies C22 and C21. The forward fitting strategy is suitable for a scope baseline and reverse fitting is suitable for a game baseline. M23 is the most commonly seen strategy, where the core game idea evolves iteratively. In this strategy, the designers need to work through various stages such as content exploration, translation, detailing, etc. while frequently revisiting the core concept as depicted in Figure 4.

Each of these strategy groups presented above aid designers in answering specific questions regarding the process of educational game design. The summary of the strategy groups and the questions they answer is presented in Figure 11.

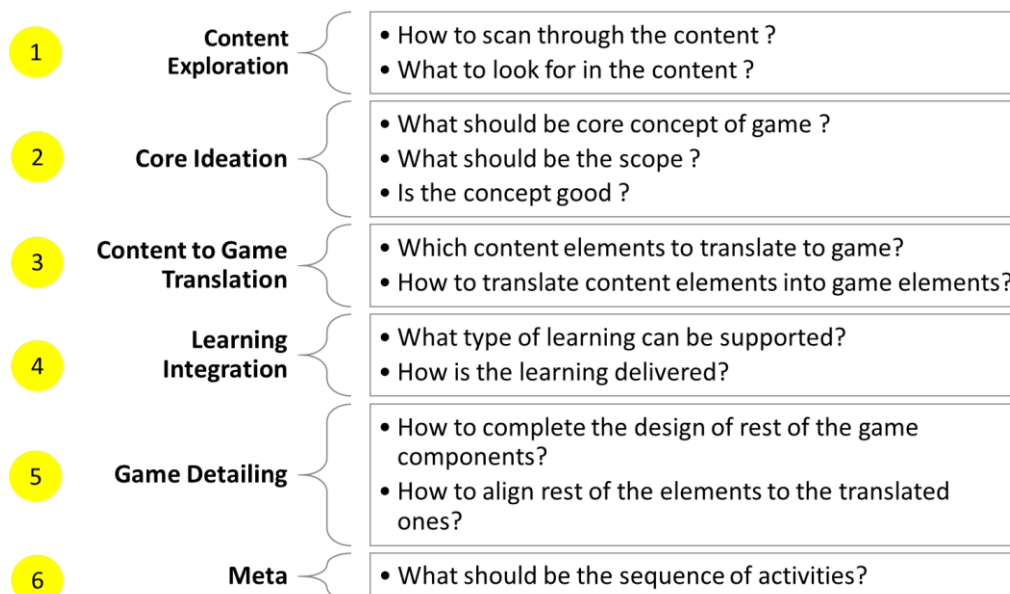


Figure 11: Mapping Design Strategies to Design Questions

In figure 12, we illustrate how designers can use a selection of the strategies for endogenous design of game for learning about ‘Rocks’.

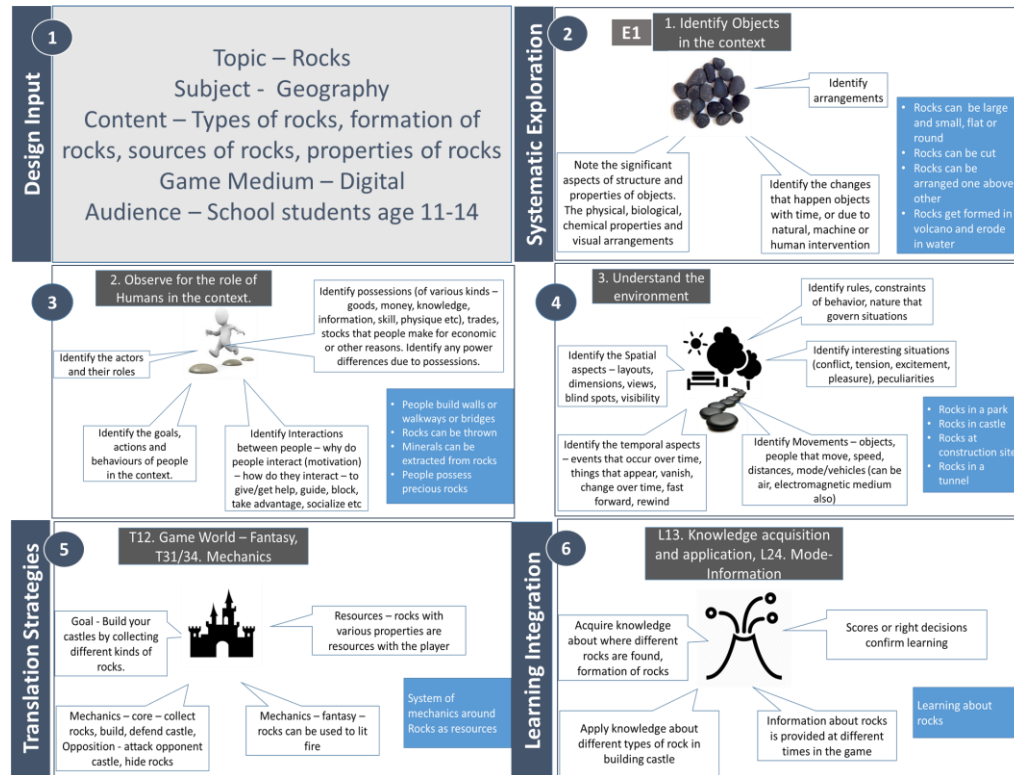


Figure 12: Illustration of steps for generating game on “Rocks”

CONCLUSION

Educational games are expected to be fun and educational at the same time. Endogenous design, wherein the gameplay emerges from the educational content, unifies the act of playing and learning. Games with endogenous design provide intrinsic motivation for learning by making it fun. However, research in educational game design has not focused much on the methods of creating endogenous design. Our research is one of the early attempts to fill this gap by presenting the strategies for endogenous design. These strategies can aid designers to answer a range of questions regarding content exploration, ideation, and translation towards design of endogenous educational games.

In this paper, we described how we extracted and analyzed the tacit knowledge of participants, using the protocol analysis method. The isolated strategies employed by the participating designers are aggregated, categorized, extended and systematically organized for use in future practice. Though further work is required to claim empirical validity of the proposed strategies, this paper is a step towards providing designers with guidance on endogenous design. With the newfound guidance, designers have choice to create delicious broccoli dishes besides continuing with chocolate coating of broccoli.

Limitations and Future Work

Though we selected a sample size that was methodologically adequate and led to good beginning for future design guidance, a wider sample may lead to discovery of divergent cases. In addition, we restricted the design activity to a single session of three hours. In this duration, designers conceptualize a game but do not create a working prototype to test the playability of the game. While the process of conceptualization is sufficient to study the strategies, prototypes would help study their impact. Further, we

requested participants to create the design individually, whereas in realistic setting designers often work in groups. This limited the participant's ability to develop and validate ideas quickly. Lastly, our scope was confined to middle school topics, therefore generalization to different groups such as kindergartners, graduates and adult learners may need further investigation.

Game design researchers can extend our work by experimenting with participants having varied backgrounds, and by addressing different educational domains. Researchers can also focus on specifics such as identifying any patterns in the content space and suggest their mapping with available patterns in game design (Bjork et al. 2004). As a part of our ongoing work, we plan to develop and validate a framework of strategies for practical use by designers. We expect our current and future research will help designers realize the promise of making educational games fun and educational, more consistently.

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