Endogen: Framework for Designing Endogenous Educational Games

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ABSTRACT
Cohesion between content and gameplay can lead to games that are educational and enjoyable at the same time, making them effective. Endogenous designs, wherein the game elements emerge from the content, lead to such cohesion. However, endogenous design is not commonly observed in practice. Lack of guidance on conceptualizing endogenous design is an important factor hampering production of effective educational games.

In this paper, we present 'Endogen' framework for designing endogenous educational games. The framework synthesized using the 'function-behavior-structure' approach is composed of a set of design strategies that we discovered in our recent work. It is validated using a multi-method approach wherein designers use the framework to design games and then rate it on various parameters. Results indicate that Endogen achieves the stated objective of creating endogenous design, therefore offering exciting content integration possibilities for game designers.

Keywords
Endogenous Design, Game Design Framework, Design Strategies, Educational Games

INTRODUCTION
Educational games promise to make learning enjoyable. This is possible when the act of playing and the act of learning become inseparable. Endogenous design, wherein game elements are generated from the content elements, can lead to such seamless integration (Malone 1987, Rieber 1996, Habgood et al. 2005, Squire 2006). In endogenous design, gameplay creates a deeper connection with the content, ensuing that playing and learning thrive on each other, leading to superior motivation (Habgood and Ainsworth, 2011). However, exogenous designs, created by inserting educational content into an unrelated gameplay are commonly seen in educational games. This is unsurprising because designing games that seamlessly integrate content into gameplay is challenging and the efforts involved in designing endogenous games are higher.

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Endogenous designs require topic specific extraction of elements from the content and translation into games, unlike exogenous designs, where pre-built pieces of games can be inserted into the content. These challenges in creating endogenous design can be overcome with availability of appropriate guidance. However, review of current literature indicates lack of such guidance. Despite abundant literature and frameworks on integration of learning and games (Arnab et al. 2015, Plass et al. 2014), very few papers provide strategies through which a topic can be 'translated' into a game (Belotti et al. 2010). Our research aims to address this gap.

The first stage of our research focused on discovering strategies for endogenous design. Design strategies typically imply a set of tactics or a plan of action. Gericke and Blessing (2011) describe a strategy as "a list of actions taken by the designer in order to transform initial brief into a final design". We adopt a more inclusive, broader definition where design strategies are the individual tactics, techniques, methods, steps, activities, and combinations of these elements, employed by designers to achieve the design goals.

Our approach to discovering design strategies was through studying game design activities and analyzing them using the 'Think Aloud Protocol Analysis' method (Ericsson and Simon, 1980). Several strategies emerged through our studies that support (i) Exploring and extracting content elements, (ii) Translating the content elements into game elements, (iii) Generating game ideas based on content elements, and (iv) Elaboration of design. Apart from these, we also observed meta-strategies that suggest sequence of actions, approach to convergence, idea verification techniques and so on. This research (along with the emergent strategies) was published in our earlier paper (Athavale and Dalvi, 2019).

The identified strategies can be far more effective for practical use when they are integrated, organized, and presented in a coherent format. A design framework provides such an integrated view of related concepts and a broader understanding of the phenomenon of interest (Imenda 2014, Liehr and Smith 1999). Apart from advancing academic scholarship, a framework intends to enhance design practice. Therefore, we developed a framework, named Endogen, to assist designers in designing effective endogenous games. The development and validation of the framework is the second stage of our research and the focus of this paper.

The proposed framework is developed using the 'Function-Behavior-Structure' (FBS) approach described by Rosenman and Gero (1998). Strategies identified as part of our preceding work, constitute the building blocks of the framework. Currently, the framework is manifested in the form of a board, a set of strategy cards, and supporting material. The practical utility of the framework is validated through a multi-method approach. Results indicate that the framework will be of great value to the designers, design teachers, education technologists and academicians, in synthesis as well as appreciation of educational games. Validation studies also brought out shortcomings and ideas for future extensions.

BRIEF REVIEW OF DESIGN FRAMEWORKS AND MODELS

Existing practical and theoretical approaches towards synthesis of design frameworks act as guidelines for the development of our framework. We evaluated papers that described design models, methods, frameworks in the field of educational game design. Most papers describe the purpose and structure of models, but the approach to development is rarely elaborated. For example, Mitgutsch and Alvarado (2012) proposed the Serious Games Design Assessment (SGDA) framework with little elucidation on the method used for the development of the framework.

In papers that explain the development, two kinds of approaches are observed: ground-up and derived. In the derived approach, new models are created through modification, combination and expansion of existing models. For example, the Design-Play-Experience model is a specialization of Mechanics-Dynamics-Aesthetics model (Winn, 2009). The RETAIN model is built by combining elements of Gagne's and Keller's models (Gunter et al. 2006), and the LM-GM model is based on the mapping created between pedagogic and game elements extracted from respective domains (Arnab et al. 2015).

Ground-up models are developed using atomic elements and structures. For example, the model proposed for analysis and design of persuasive games (de la Hera, 2012). De la Hera's approach is through building the three essential characteristics of a model — 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 can guide designers in making decisions during synthesis of persuasive games.

Another example of ground-up development is Serious Games Framework (SGF) proposed by Hall (2015). His approach to developing the framework is using existing literature in the fields of learning motivation and game design. This framework is derived through the analysis and deconstruction of games into elements that have specific pedagogical qualities. The structure of framework begins as a collection of resources arranged logically. It further evolves through iterative validation using case studies. This framework consists of a conceptual layer, a design process and a set of activities within the process, and supporting tools.

One more example is the Applied Game Design Model for integrating content in gameplay, proposed by Deen (2015). His approach to framework development is through building a sequence of stages. He begins by breaking down the learning process into steps and then introduces a step for transformation of restructurable content elements into the game. The development follows the standard iterative improvement process, which is based on prototyping and feedback. We also find few other examples of ground-up models wherein the authors begin with atomic elements and arrange them into interrelated categories to synthesize a design framework (Antle and Wise 2013, Melcer and Isbister 2016).

The derived models created by extension, specialization, combination, and mapping of existing models are easier to develop and validate because the underlying models are already established. On the other hand, ground-up models developed using basic building blocks have to demonstrate their soundness through use of appropriate methods for synthesis and validation. Ground-up models need an iterative approach where each version is validated through empirical evaluation. Successive iterations lead to improvements and framework maturation over a period.

THEORETICAL BASIS FOR SYNTHESIS OF FRAMEWORK

Our framework is developed using a ground-up approach based on the function-behavior-structure (FBS) ontology. The FBS ontology offers a well-established baseline for describing and developing design artifacts as well as design processes. Development begins by defining the function of the framework, then building the structure (components and their relationships), and finally defining the behavior (the attributes derived from its structure). The connections between function, behavior, and structure are developed through experience, experiments, and hypothetical causal models. The guidelines for defining the function-behavior-structure are derived from the supporting literature.

Function: Koskela et al. (2014) indicate that the primary function of a design framework is to provide an explanation and direction for practice. The framework should act as a tool for decision and control, communication, learning and transfer. The Delft Design Guide (Van Boeijen et al. 2014) informs that a design method should help designers by reminding them of the essential steps for achieving goals without too many detours. The framework can serve both descriptive (*how things are*) and prescriptive (*how things ought to be*) purposes.

Structure: Chakrabarti and Blessing (2016) propose that the purpose of 'models of design' is to explain either the process of design and the elements within, or a set of constructs and relationships between them. The process, elements, and relations together form the structure of the model. Gericke and Blessing (2011) indicate that the design process typically consists of stages, activities, and strategies. Similarly, Hubka (1983) suggests that the structure of design process consists of partial processes, phases, and detailed design steps. Apart from the internal components and interconnections, the visual manifestation is also a part of the structure.

Behavior: According to Rosenman and Gero (1998), the behavior of a model is the manner in which it responds to the environment and external actions. The behavior of the framework can also be interpreted as the expected characteristics of the framework.

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

- The framework should provide explanation and direction for practice, in our case guide game designers towards achieving endogenous design
- The structure of framework should contain stages, activities, and strategies
- The development of framework would begin with identification of building blocks, which would be the strategies identified in our preceding research
- The behavior i.e., the expected characteristics, performance objectives of the framework should be defined and validated
- An iterative process should be followed for development

SYNTHESIS OF ENDOGEN FRAMEWORK

'Endogen' is coined from the words Endogenous Generation. The name indicates the utility of the framework, which is enabling generation of game elements from educational content. We call it a design framework, and not a model or a method, as it implies a flexible representation of interconnected concepts. The framework consists of a board, which indicates the design process along with necessary steps, and supporting strategy cards.

The function of the framework is to aid educational game designers, especially novice designers, by guiding them through a design process. Strategies provided at every step in the process enable endogenous design. These strategies help designers in identifying and extracting gameable elements from the content and translating them into game elements. The framework can act as (i) a fully guided process for those who seek end-to-end support and as (ii) a reference for those who seek limited support.

Structure of the framework consists of two parts, internal components and external manifestation. The components of the framework are based on the strategies and their groups identified in our preceding studies.

Figure 1 shows the groups and their prominent sequence (stages) observed in our earlier studies. According to this sequence, the game concept is gradually developed through stages such as extraction, translation, and detailing. Stages of ideation appear multiple times between other stages and double up as checkpoints for the verification of earlier idea.

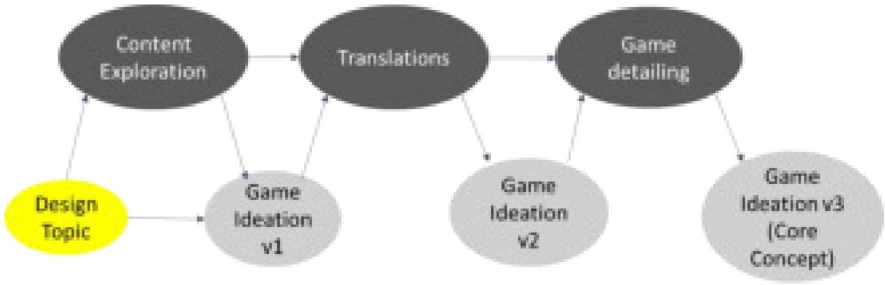

Figure 1: Prominent Sequence of groups

Figure 1 depicts a sequence, which is consistent with the three stages commonly found in design models: problem definition stage, conceptual design stage, and detail design stage (Gericke and Blessing, 2011). In the above sequence, the problem definition is partly covered in the design brief and partly in the content exploration stage. Conceptual design is spread across game ideation and translation stages. The stages and sequence in figure 1 were used as a starting point for developing our framework.

We improved the initial sequence to maintain consistency with processes identified by existing literature. Firstly, game design is an iterative process and figure 1 does not represent the same, so we converted the process into a loop. Secondly, ideation stages v1 and v2 were repurposed as divergence stage and convergence stages, based on the method proposed by Jones (1992). Although concepts can be verified at every stage, an explicit verification stage was added. These improvements were made incrementally by gathering user feedback. The sequence in figure 2 appeared to be stable, and is the basis for development of our framework.

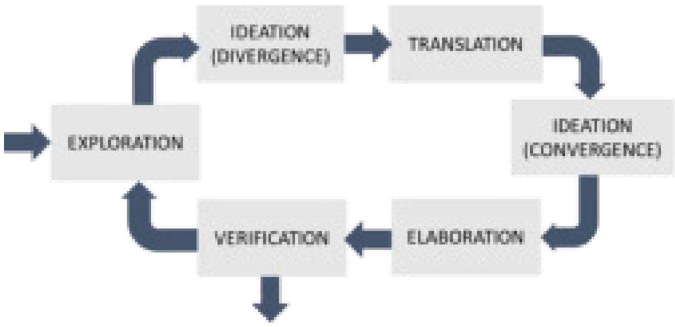

Figure 2: Improved Sequence

The components of the framework i.e., the discovered strategies underwent systematic appraisal before becoming part of the framework. While most strategies became part of the framework without much change, few underwent changes such as combining, splitting, and detailing. For example, in the strategy 'connect the content elements', specific details about connecting the actors with the objects through actions etc. were provided. New strategies were introduced to fill any gaps and form a continuum, and few others were added as extensions.

Concurring with Gericke and Blessing (2011) our framework consists of design stages, activities, and strategies. There are six stages indicated on the board, identified by a unique color. Each stage has a number of steps, and each step requires the designer to perform an activity or use a set of strategies. The arrangement of the stages is dictated by the sequence in figure 2. The supporting strategy cards with color and step number corresponding to the board contain strategy details (example shown later in figure 5).

Initially, the game of Ludo was the inspiration for visual design and layout of the board. As we iterated, a radial layout was created and finalized (see figure 3). The radial layout has a notion of circular 'movement' inspired from the movement in board games. The circular depiction also reflects the iterative nature of game design process. The arrangement of stages and steps along the circular path also makes it easy to trace the progress. The structure of our framework resembles the circular structure of the game design process, by Dukes (2014).

Figure 3: Endogen Framework

The expected behavior of the framework was articulated in terms of the performance objectives. The framework should:

- Facilitate overall design process with guidance at each step
- Facilitate endogenous design creation through specific strategies
- Afford suitability for users with varying expertise (in game design or otherwise), for use across different periods and for varied type of content
- Provide flexibility and ease of use. Designers should be able to use the complete process or just the selected strategy and steps

The validation studies evaluated the framework against these objectives.

DESCRIPTION OF FRAMEWORK STAGES

The six stages in the framework are Exploration, Core Design (Divergence), Translation, Core Design (Convergence), Elaboration, and Verification (see figure 3). Two minor stages, Preparation and Reflection are part of the process but are not shown in the figure.

Preparation Stage: The preparation stage (step 01), informs the designer about the prerequisites of game design. The Endogen framework focusses on enabling educational game design, and does not explain fundamental concepts of game design. Therefore, basic knowledge of game design is a prerequisite. The framework nevertheless includes a sheet, which elucidates terminology used in game design. In the preparation stage, the designer should acquire the design brief, required materials, and internet access. Designers may also invite subject matter experts, potential players, and co- designers as necessary.

Exploration Stage: The exploration stage has six steps (02 to 07). The first step (02) informs designers to scan the content, read the reference material and divide the content into logical chunks. This strategy helps designers to identify chunks that can be incorporated a single game or a single level in the game. Not all the chunks need to be considered in same game. The next step (03) asks designers to recognize core concepts and relationships between them. There can be more than one core concept in each topic. For example, in the topic 'Force' in physics, the core concepts can be force, acceleration, motion, Newton's laws etc. Sometimes the core concepts can be abstract, such as a bank account, right to education. Relationship between concepts also needs to be identified, for example 'Force causes acceleration'.

In step 04, designers are guided to explore the selected chunks in a systematic manner. This strategy involves identifying various dimensions of the content. This includes actors (who perform, trigger the actions), objects (on which actions are performed), properties and arrangements of the objects, interactions (between actors, between actors and objects), environment (space, time, events, situations, constraints, etc.) and so on. For example, actors can be human, systems and nature. Objects can be physical, chemical, biological etc. and properties can be weight, transparency, malleability, conductance, color/darkness, magnetic, sounds/silence etc. Actions on objects can be varied e.g. press, move, heat and so on.

Strategies in step 05 ask designers to use specific lenses to examine the content. This strategy is useful when systematic exploration does not yield many useful elements. The human centric lens suggests that the designer observe/imagine what humans would do in specific content-related context. For example, in the topic 'Rocks' in geography, the role of humans could be to find, process, and use rocks for various purposes. Similarly, object centric and situation centric lens can be used.

Step 06 encourages the designer to observe and recognize peculiar arrangements, unusual elements, properties and conditions as well as inherent contradictions in the content. These can lead to unique resources and mechanics in the game and contribute to novelty. The strategy in step 07 is to connect the identified elements in meaningful ways. Figure 4 shows an example of how these elements could be connected in preparation for translation to characters, mechanics, resources etc.

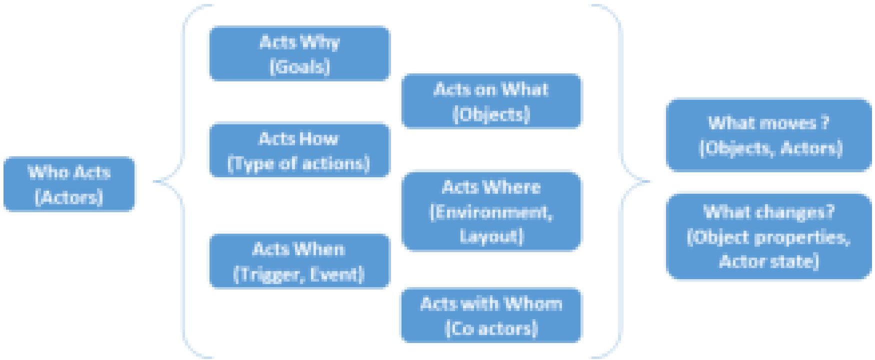

Figure 4: Connecting Content Elements

Core Design (Divergence) Stage: The strategies in the four steps in this stage (08 to 11) guide designers to (i) decide the game medium, (ii) generate ideas for gameworld, (iii) generate ideas for goals, paths and the movement, and (iv) create a list of gameplay possibilities. Gameworld can be generated using various strategies such as simulation of real word, creation of fantasy world, creation of a representation world (especially in case of physical objects) and a mix of these.

The game goals can be derived from goals that humans pursue in relation to the content. For example, in the topic ‘Force’, a possible goal is to move an object from point A to B with least effort, time etc. The goals when related to the fantasy world could be destroying the enemy by shooting a projectile. The possible paths could be travel upstream, downstream, on curved roads, smooth surface, on rails, wires, airborne, and so on. The movement in this case is that of the object on the path, caused by force. The combinations of goals, paths, movement and gameworld lead to gameplay ideas. Gameplay ideas could also be borrowed from earlier games. It is not necessary that every element in the game be endogenous. However, in such cases, the gameworld, goals and path elements need to be aligned appropriately.

Translation Stage: While the translation of goals, paths and gameworld is situated in earlier stage, translation of actions into mechanics, and objects into resources is placed in this stage. After the selection of mechanics and resources, earlier decisions on goals, paths, gameworld and gameplay can be revisited. There are six steps (12 to 17) in this stage. In step 12, designers are requested to reimagine the content elements as game elements using techniques such as morphological charts to generate options.

The strategy in the step 13 informs designer to transform the identified objects (real or abstract) from the content into game resources. Once the core resources are transformed from content, fantasy objects and properties can be added. For example, in the topic ‘Rocks’, fantasy properties such as ‘antigravity’ can be added to make the game fun. However, while adding fantasy elements, care needs to be taken that it does not affect the authenticity of learning content. Separate score buckets can be created to demarcate elements that are not truthful to subject matter so that learners can distinguish authentic content. The selected resources also need to blend into the gameworld.

Next, the selected resources should be classified as mobile, immobile, exchangeable, combinable, breakable etc. This classification enables the design of appropriate mechanics to act on them. Further, designers need to identify objects that can move as tokens in the game. For example, in the game of 'heat', resources such as metal, water etc. can move. Finally, designers should observe patterns and transitions, such as, equilateral triangles could be arranged into a hexagon. These properties can be used as either mechanics, powers or layouts.

In steps 14 and 15, a system of mechanics is created using strategy cards shown in figure 5. The core mechanics can be generated from several sources such as the human actions on objects, interactions between humans, between humans and system, etc. Opposition mechanics are generated by offering counter actions and creating obstacles to core mechanics. For example, in the game of fundamental rights, the 'opposition mechanic' is a situation that undermines the rights of citizens.

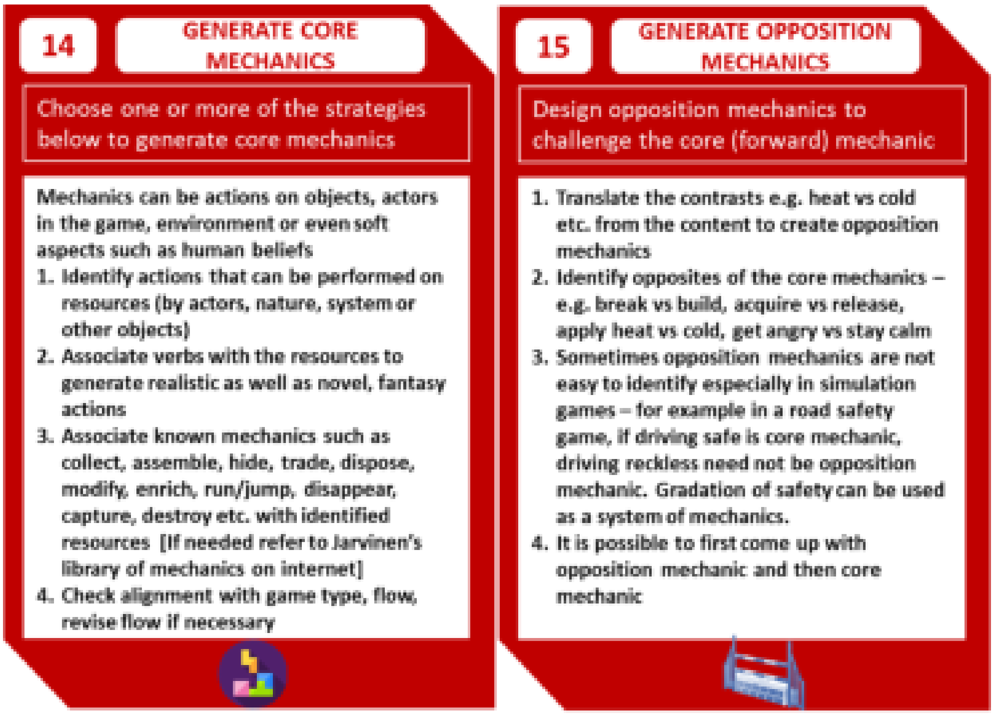

Figure 5: Strategies Cards to generate Mechanics

Step 16, is a check on how learning is enabled through the translated elements. Designer reviews: game mechanics (which enable learning through repeatable action), gameworld and resources (which afford through visualization) and game situations (which creates learning through application of knowledge). If the elements are not sufficient to meet learning objectives, more elements need to be explored and translated. Finally (step 17), designers attempt combinations of the generated elements e.g. gameworld, paths, mechanics, and resources to generate potential game ideas.

Core Design (Convergence) Stage: The design convergence stage has four steps (18 to 21). First step is to shortlist two or three ideas by discussing with co-designers or potential players. In the next step (19), player interactions are designed. This includes deciding how the player competes or cooperates, moves her token/character/herself, interacts with each other etc. For example, in the basic chemistry game, the player can change one element of the equation in one turn or exchange components with other players. Players could also willfully provide wrong elements and hide some elements in an attempt to sabotage opponent's progress.

In step 20, identifying and fortifying the ‘gameness’ is in focus. All the elements identified and translated can be combined but this may not be adequate to compose a good game. The ‘gameness’ can be achieved through a unique contest, a challenge, a unique rule that motivates the player to play and win. While standard contests that work in other games can be incorporated, the endogenous nature and novelty arises from finding something unique in the content. This can include use of unusual patterns and properties, unexpected behaviors, constraints, unique situations, visuals patterns, human habits etc. After deciding the idea that offers the best ‘gameness’, the concept is finalized.

Elaboration Stage: There are six steps (22 to 27) in this stage. Step 22 guides designers to list and work on the missing as well as weak elements in the design. The step 23 is defining rules for starting, finishing, turn taking, and scoring in the game. Rules can be derived from prior games and they can be derived from content as well. For example, ‘rights cannot be destroyed’ is a rule emergent from the topic ‘fundamental rights’. Step 24 focuses on creating events that can change course of game, its pace and rebalance the advantages of players etc. At step 25, the aesthetics, visual design, and the learning elements such as feedback, progression, are addressed. At step 26, designers are asked to refine the design by eliminating extraneous and incoherent elements. The last step (27) is prototype creation.

Verification Stage: The four steps (28 to 31) in this stage provide strategies to verify the design qualities. The strategies to check completeness of the game include the use of a checklist and mentally playing the game. Player engagement can be verified using player feedback and expert opinions. Content coverage can be verified by revisiting the reference material. Endogenousness can be verified using a rubric that we developed as a part of our research and made available as supporting material. At the end of this stage, depending on the gaps in the concept, designers can iterate through the entire design cycle or parts of it. Once the concept is ready, the process ends (step 32).

Reflection Stage: Once the design is final, the designer can reflect on the qualities of design as well as the strategies used. Designers can also note additional strategies that they used, and share them with researchers to improve the framework.

VALIDATION OF FRAMEWORK

When new frameworks are developed, validation is essential to bring credibility to its claims. In design research, frameworks are primarily validated through the significance of their use (Barab and Squire 2004, Messick 1994, Weber 2014). We validated the utility of the framework on four dimensions based on objectives defined earlier. The dimensions and their corresponding operational parameters are listed in figure 6.

In design research, various empirical methods are used to validate frameworks. To achieve our validation objectives, we select three established methods:

1. Comparative studies
2. Design workshop and focus group interviews
3. Longitudinal design assignments

These methods were chosen to cover various conditions of usage such as duration (single session vs. long duration), types of users (game designers, non-designers, education technologists), and the level of details (design process with and without supporting strategies). Studies conducted using multi-method approach help in the triangulation of results.

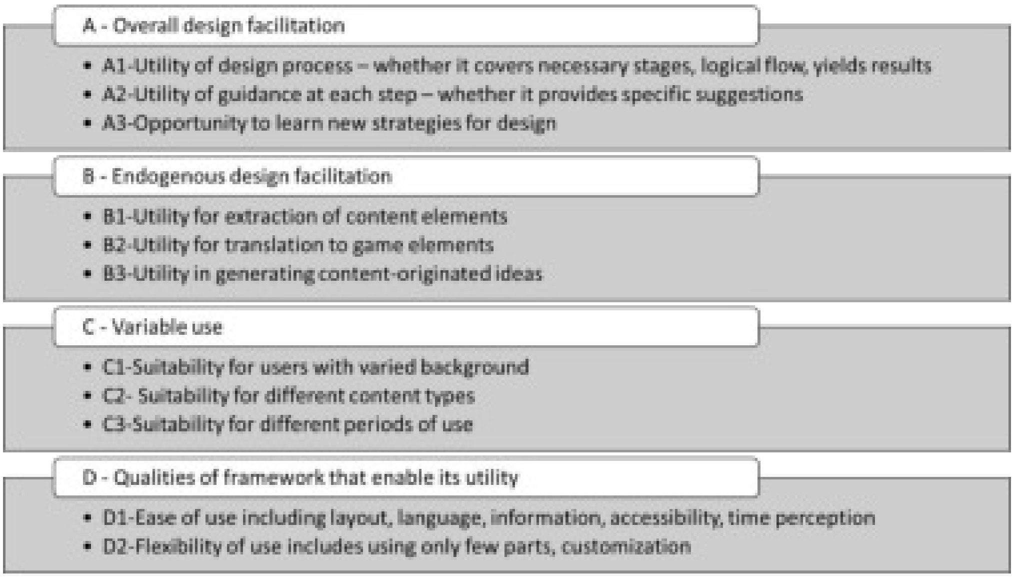

Figure 6: Dimensions of Validation

Studies and Results

A separate protocol was created for each method. Participants were required to conceptualize a game in each of them using the Endogen framework (except for control group in comparative study, where a placebo framework was supplied). The protocol for each method and the results obtained are described further.

Comparative study: We conducted control and experiment sessions to compare the utility of the Endogen framework with a placebo framework. The placebo framework was specifically created for the session. It had macro guidance on the design process but did not have specific steps and was devoid of any strategies. Ten participants with varied backgrounds participated in the studies, five in each session. Five varied educational topics from middle school were chosen and assigned in first session and were repeated in the second session. Both sessions were scheduled for a duration of three hours.

A questionnaire was designed to capture feedback using a five-point Likert scale for various parameters. The utility of framework was assessed using a combination of ratings taken from the participant and an independent evaluator who observed the sessions and evaluated the concepts. Considering the small number of participants, we relied on qualitative data analysis, which considered the ratings as well as observations.

The Endogen framework was rated better than the placebo on the ‘usefulness of guidance at each step’ (A2), and ‘opportunity to learn’ (A3) parameters; however, it fared at par on the ‘design process’ (A1) (refer to figure 6 for codes). This is not surprising since both the frameworks specified a design process, but only Endogen had supporting strategies. In both the sessions 3 out of 5 participants could complete their concepts, so we could not ascertain whether Endogen facilitated the completion.

The Endogen framework performed better on ‘extraction and translation’ (B1/B2) but placebo framework fared better on ‘idea generation’ (B3) aspect. This was unexpected but can be attributed to the fact that placebo framework is unconstrained. In the ‘variable use’ dimension (C), the Endogen framework again did better on ‘suitability for users with different backgrounds’ because participants from non-design backgrounds could use the guidance. Other variable use measures were not tested in this study.

On the 'qualities of framework' (D), the placebo framework turned out better on 'ease of use' and 'flexibility' because placebo was open-ended with significantly less structure. In summary, the Endogen framework performed better on guidance at each step, facilitating endogenous design, and indicated suitability for users with no game design background.

Workshop and Focus Group study: We conducted the workshop by selecting users having a background in education technology rather than game design to bring a divergent perspective to validation studies. Their knowledge of instructional design frameworks, educational techniques, tools, methods of learning, and exposure to designing for a variety of content was expected to provide differentiating feedback. This study specifically helped ascertain 'variable use' dimension (C).

Four PhD students from educational technology department of a reputed school in India were selected for a three-hour workshop. Notes on game design as well as the Endogen framework were shared with them in advance. Educational topics were given at the beginning of the session, and each participant was asked to design a game concept. At the end of the session, we conducted focus group interviews to collect feedback. The focus group technique encouraged discussion between participants leading to richer data, which was coded and analyzed (a four-point scale of low-average-high-very high was used for some dimensions). Figure 7 shows a photograph of the workshop in progress.

Figure 7: Focus Group Session in Progress

Between the three methods, focus group interviews provided the most valuable feedback for improvement. On the 'overall design facilitation' dimension (A), participants suggested a change in the arrangement of stages, specifically, making ideation a parallel activity. In addition, there was a suggestion to reduce the number of steps. The 'utility of steps' (A2) was reported to be very high in the exploration stage, high in translation and average in rest of the stages. The 'opportunity to learn' (A3) was also reported as 'very high' as the participants found new ways to look at the content.

As part of the 'endogenous design facilitation' (B), the exploration stage (B1) was reported as most useful as in the previous method. However, it was indicated that the framework did not help in idea generation (B3) and strategies should be included for the same.

The 'variable use' dimension (C) was best validated through this group as the participants belonged to varied backgrounds. The 'suitability for users with varied background' (C1) was confirmed from this study. In the workshop, 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.

The participants also reported that framework was suitable for different types of content (C2). This could also be independently verified since we had assigned topics belonging to different content type (factual/conceptual/procedural/behavioral) 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. Improvements were suggested by the participants on the 'qualities of framework' dimension (D), especially simplifying the terminology and language.

In summary, the focus group study confirms the utility of the framework for users with different backgrounds. It also reinforced earlier findings that the content extraction strategies are very useful. The study also brought out the areas of improvements such as simplification of language, and the inclusion of ideation strategies.

Longitudinal study: In the two methods discussed previously, feedback was based on a single design session. In a single session, participants may miss the finer details in the framework, but a longitudinal study can provide opportunity to uncover them. Hence, we conducted longitudinal studies over a period of a week. Five participants agreed to participate and design game concepts by using our framework. At the end of the week, four participants submitted their ideas, and we conducted semi-structured interviews with them and analyzed the data.

The feedback on 'overall design facilitation' dimension (A), indicates more focus on exploration and translation stages, and less on elaboration and verification, despite participants having time at their disposal. It appears that once the designer has identified the building blocks, elaboration and verification do not require meticulous guidance. Moreover, endogenous design is enabled predominantly by the exploration, core design, and translation stage. The 'opportunity to learn' (A3) was enhanced due to the longer duration and participants claimed that they were able to master the framework in a week.

Within the 'endogenous design facilitation' dimension (B), there was no new finding other than reconfirming its utility. Regarding the 'variable use' (C), this study confirmed suitability for longer use. Participants informed that they referred the framework every time they worked on the assignment in the weeklong period. Longer use enabled them to refine the game concept. There were no additional findings on the 'qualities of framework' dimension (D). We anticipated that some participants may modify the framework in the one-week period but this was not observed.

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

Summary: Based on the findings from the three studies, it can be inferred that, the framework provides expected value on all the dimensions. As part of the 'Overall Design Facilitation', users appreciated the organized approach, completeness of the process, and the strategies furnished at each step. It could be inferred that elaboration and verification stages were less frequently used.

On the ‘Endogenous design facilitation’, which is the core purpose of framework, users reported that strategies were extremely useful for extraction of content elements and translation to game elements. One participant expressed that “endogenous design came naturally while using the framework”. Overall, the validation studies confirmed that the purpose of the framework of providing guidance on endogenous design has been adequately met.

Results indicated 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. The suitability for designing games with factual, procedural, and conceptual content was confirmed based on the outcomes for varied topics. 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 framework needs further improvement to make it easy to use. This could possibly be done by providing multiple examples as was requested. 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.

STATE OF THE FRAMEWORK

The state of the framework is indicated by its present utility, limitations, and future work.

Present Utility

The framework provides a guided process with a set of strategies at every step of the design process. This comprehensive process enables designers to cover all 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”. The framework is well suited for novice designers and experienced designers can use selected strategies.

Academicians and education technologists often need to use games as a medium of teaching. They tend to rely on known game examples and seek support from game design experts. This framework can help them become independent in appreciating, and designing games. Teachers in game design can also use this framework as a reference to create their coursework and assignments. Game design students in turn can use it as a reference for assignments. Game analysts can use parts of the framework such as the verification strategies to evaluate the ‘endogenousness’ of games. Finally, learners can use the framework to make their own learning interesting. This is in concurrence with the idea of Klopfer et al. (2009), that learners should find elements that are inherently fun in the content and ‘toy’ around with them.

Limitations and Future Work

The validation studies also identified some limitations of the framework. Few participants indicated that the framework appeared overwhelming due to the number of steps, and suggested that a staggered layout can address this problem. Another suggestion was rearrangement of the stages, especially making the ideation stage parallel. Such rearrangement of stages as well as staggered layout would require further iterations and it can be taken up as future work. Participants also suggested the need to include ideation strategies as part of the framework. We have decided to exclude them for now, as multiple ideation methods are available in literature.

Apart from the shortcomings of framework found in the validation studies, a few other limitations of our research need to be mentioned. The studies for discovering strategies were conducted with middle school topics; therefore, suitability for other segments such as higher education needs to be assessed. Besides this, the scope of data collection as well as validation studies was limited to building concepts rather than playable prototypes. Although the creation of good concepts provides adequate proof to illustrate the utility of strategies, playable prototypes could enhance the claims.

Another limitation 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 require integration of pedagogic principles, which earlier frameworks such as LM-GM have addressed. In Endogen, the insertion of pedagogic principles is hinted in a few steps, but explicit strategies to deal with scaffolding, assessment, feedback, progression, mastery etc., could be incorporated in future.

In future, our work can be extended through discovery and inclusion of additional strategies. With additional research, strategies specific to types of content may be discovered. Variants can also be created for specific disciplines such as engineering, commerce etc. The framework can also have fast-track options for experienced designers, as well as a simplified version for novices. Presently the framework is technology and medium agnostic but variants for emerging technology such as AR/VR are possible in future. A digital version will be the natural advancement of the current physical manifestation. The digital version can have advantages such as adaptive guidance based on type of user. Our claims can be strengthened further through validation from the wider community of educational game designers.

CONCLUSION

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). Our research follows similar characteristic. Building on our earlier work of discovering design strategies, we synthesize a framework named Endogen, to aid in design of endogenous educational games.

Design frameworks, freshly minted from research labs promise academic advancement as well as practical utility. While most frameworks advance existing knowledge, the main criticism is that few are useful in practice. From a user's perspective, the framework needs to provide novelty, credibility, flexibility and adaptability, apart from the core utility. In the course of synthesis of the framework, we strived to address these aspects and some of these were confirmed through the validation studies. We summarize their presence in Endogen.

Projecting novelty i.e., articulating the specific value that the framework brings to the designer is the primary aspect. The novelty in 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. This is a vital contribution towards amalgamation of learning and playing in educational games.

The second aspect is establishing credibility regarding the approach used for the development of the framework. Design frameworks can be developed using multiple approaches. When the rationale for construction is unconvincing, users are less likely to adopt the framework. Endogen uses an approach where its synthesis is based on the data collected from practicing designers. Therefore, there is a high probability that designers will be able to relate to it.

Designers and creative professionals strive for freedom while the notion of 'framework' conveys structure, constraints, and processes to their mind. Yet, structures and processes are important, as they bring assurances towards achieving outcomes. Addressing this contention can be seen as the third aspect. The Endogen framework offers balance between structure and freedom. Designers have the choice between using the complete process and using selected strategies.

The fourth aspect is enabling users to adapt frameworks according to their specific needs. Endogen framework can have variants for different type of contents and different type of users. Digital embodiment of the framework is an obvious possibility. A digital version can act as an assistant to the designers by providing step-by-step guidance, contextual recommendations and real time collaboration with multi located teams. It can also open up the possibility of machine-assisted generation of educational games.

Appropriate positioning of the framework to avoid mismatch of promise and expectation is the fifth aspect. The Delft Design guide (Van Boeijen et al. 2015) suggests that design guides are like recipe books, which provide information about ingredients and processes, but do not guarantee tasty food. The Endogen framework is no different. It provides essential ingredients for endogenous design of games, but the onus to extract, translate and connect the elements to create a good game, is still with the designers.

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