Shih, J. L. et al. (Eds.) (2019). Proceedings of the 27th International Conference on Computers in Education. Taiwan: Asia-Pacific Society for Computers in Education

Core Gamification of Learning Activities through a Method based on Information Structure Manipulation

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Abstract: Gamification, the use of game elements in non-game contexts, is a popular method to design motivating, enjoyable learning experiences. It is often applied through external rewards like leaderboards and achievements. Research shows that these rewards can negatively affect intrinsic motivation. One way to avoid this issue is by applying the game elements to the internal design of the learning activity. This approach is called Core Gamification. However, there are no concrete methods to apply Core Gamification to learning activities. This paper presents a method for the Core Gamification of learning activities based on information structure manipulation. In this case, information structure manipulation is not done by the code. And they are also not just about the design of the activity. The structures are visible to the user. The manipulation is also done by the user. Case studies with verified learning effects is also shortly presented.

Keywords: Gamification, Gameful Design, Intrinsic Motivation

1. Introduction

Gamification has been associated with rewards. Most gamification approaches focus on a variation of leaderboards, points, or achievements. The goal of these rewards is to change behavior. Since these rewards are external to the activity, they can be interpreted as extrinsic motivation (Nicholson, 2015). Extrinsic motivation can be detrimental to intrinsic motivation (Deci and Ryan, 2002). Research shows that after the introduction of rewards, users become less likely to do the task when the reward is removed (Brandt, 1995).

A review of empirical studies by Zeng and Shang (2018) investigated studies published between 2013 and 2017. It states that there is a concern on the cognitive processes in the learning process. The review pointed out the work of Lee and Heeter (2017), which drew relationships between game behavior, skills, attention and comprehension. These types of work show a trend to go beyond rewards into the cognitive process that happen during gameplay. However, how to design experiences which optimize these cognitive processes? And at the same time, keeping the activities engaging.

The work of Deterding (2015) approaches this problem by defining a method to create gameful systems focused on intrinsic motivation. Gameful systems are systems which have gameful (game-like) characteristic. The method is grounded in designing systems through matching skills, motivations, and actions. The method is very broad, being usable in a wide variety of scenarios, attempting to influence experience-driven design in a general way. The work Yuan and Shang (2018) also presented a framework based on emotional design for game development. It can be used to improve or serve as guidelines for design, but it does not offer a more concrete method for designing gameplay.

While the work of Deterding does offer a general view and guidelines, there is a lack of more concrete, context-specific methods of achieving Gameful Design. When designing educational applications, we want to focus on the need for competence (Ryan and Deci, 2000). That is, we want to align the intrinsic motivation of mastering the learning target with the need of the users for competence. External rewards and systems would detract from this. To achieve this, game characteristics must not be added externally, but internally. The work of Wang (2016) defines this sort of internal gamification as

Core Gamification, where the game elements are so integrated into the core mechanics that they are inseparable.

If we remove leaderboards and achievements from the discussion, what elements from games should be used in Core Gamification? The literature points out some elements like clear actions, rules, goals, and feedback (Deterding, 2015). Those are the elements that games use to afford experiences that satisfy competence needs. Furthermore, clear goals, sense of control, unambiguous feedback are all associated with the flow state (Jackson and Marsh, 1996), a state of high involvement and enjoyment. Core Gamification should focus on intrinsic motivation based on competence needs while promoting the flow state. It can manage to do so by clarifying and redefining the actions, rules, goals and feedback mechanics of the activity.

This paper proposes a method for Core Gamification based on defining information structures derived from the learning target and designing gameplay around them. It also includes the case study of applications developed using this method.

2. Core Gamification, Serious Games and Our Approach

The work of Deterding (2015) defines gamification as the means of using game design elements in non-game contexts. In this section, reward-based gamification is defined as the gamification approaches focused on leaderboards, points and achievements as a way to reward the player for their actions. Core gamification, in contrast, refers to the gamification approaches that focus on the activity design internally. While gamification is the means to introduce game design to non-game contexts, nothing is said about the result. The result might be a gameful system, a system that involves gameful design that is not necessarily a game. When gamification is applied to software development, the result can sometimes be defined as a serious game. A serious game is defined in the work of Susi et al. (2007) as a game made for more than entertainment. Whether or not the result is a serious game or not depends on the used definition of game and on the design of the activity. As such, the use of reward-based gamification or core gamification is not what determines if the result is a game or not. Both methods can be used in the design of both serious games and gameful systems.

The proposed approach in this paper aims for the result to be a serious game. As such, it is intended for it to be a method to design the core gameplay of a serious game. The relationship between gamification, serious games and gameful systems can be seen in Figure 1.

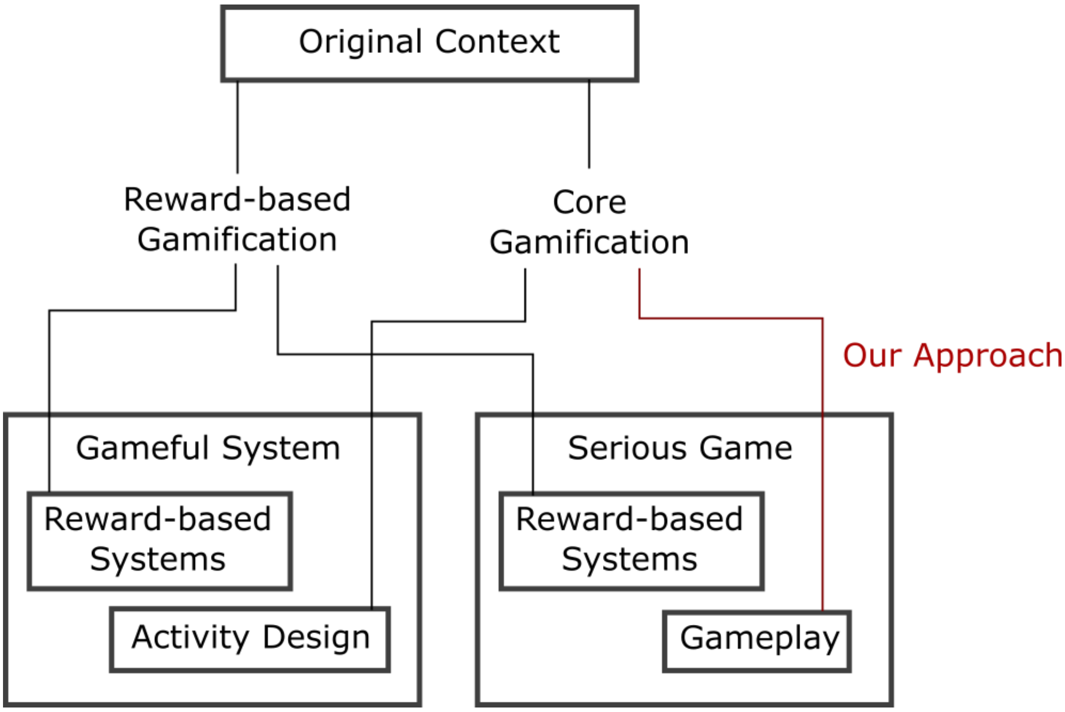

Figure 1. Diagram relating serious games, gamification approaches and the approach in this paper.

3. Proposed Method

Below is an outline of the proposed method:

- Original task analysis
  - Select subset of the original task
  - Define broad structure
  - Decompose structure
  - Define constraints
- Gameplay Design
  - Define task
  - Define goal
  - Define problem-specific constraints
  - Define end states
  - Define state space
  - Define initial state
  - Define feedback

3.1 Original Task Analysis

In this step, the original task will be analyzed so the appropriate information for gamification can be obtained. Firstly, a subset of the task will be chosen. A subset is chosen because classical learning tasks often contain parts which are not directly related to learning the target. Then, an information structure will be defined based on the learning content and on the subset of the original task. This information structure must be well chosen because the entirety of the gameplay is defined based on it. Next, we decompose that structure into pieces. These pieces are what the player can interact with. Finally, we define constraints for how the pieces can be combined. Those constraints are based on the properties of the information structure. They are closely related to the content that must be learned.

3.2 Gameplay Design

In this step, the rules of the game will be defined. While an order has been proposed for the sub-steps, the designer is likely to go back and forth during the process. First, a goal is defined. The goal represents what the player should strive for. Then, possible problem specific constraints can be defined. This allows for the creation of problems focused on a single aspect of the activity. End states are then defined. The end state defines one or more application states where the problem is considered cleared. The end states are closely related to the goal and to the constraints. Then, the state space is defined. The state space is all possible combinations of states for a given problem. Next, the initial state is defined. This is the application state that is presented at the start of a problem.

4. Case Studies

4.1 Monsakun

Monsakun is a sentence integration software for arithmetic problems (Hirashima et al., 2007) which was developed through the presented method. In Monsakun, users pose problems by choosing and ordering three sentence cards. The use of Monsakun has been associated with an increase in correctness during sentence integration. One experiment found a significant increase ($p<0.001$, $\eta 2 = 0.410$) between pre-test scores ($M=1.33$, $SD=0.79$) and post-test scores ($M = 3.33$, $SD = 0.70$), where the tests measured correctness of sentence integration problems.
The design of Monsakun is framed and explained through the proposed procedure:

- Original task analysis

- Select subset of the original task: The subset we use in Monsakun is only the integration portion of understanding as described by Mayer et al. (1985);
- Define broad structure: The main structure in Monsakun is the structure of a single problem. A problem is composed of multiple sentences such that each sentence can be mapped to a number in a mathematical expression. An increase type problem would be described in three sentences as;
  - John has three apples;
  - John buys two apples;
  - John has five apples.
- Decompose structure: A piece is defined as a single sentence which has attributes like value, referenced objects, type, etc.;
- Define constraints: Most of the constraints are intrinsic to the original problem. One extrinsic constraint is that all problems are defined by a maximum of three sentences. Another extrinsic constraint is that all problems describe additions or subtractions. Example of intrinsic constraints in Monsakun:
  - Object constraints: All sentences only reference one object and they all reference the same object;
  - Number constraints: The third sentence contains a value that is the sum of the values of the two previous sentences;
  - Sentence type constraints: The first sentence and the third sentence must describe the existence of an object. The second sentence must describe an object's value increasing.

- Gameplay design
  - Define goals: The overarching goal of Monsakun use is the understanding of arithmetic problems. The goal of a single task is for the student to construct a problem satisfying several constraints;
  - Define task: In a Monsakun task, the user must choose three pieces from the available pool and order them so that they satisfy the constraints;
  - Define task-specific constraints: Other than the constraints previously defined, each task in Monsakun provides the user with a mathematical expression and a story type. This results in two task-specific constraints:
    - The three sentences must be mappable to the provided mathematical expression;
    - The story type of the resulting problem must be the same as the provided story type.
  - Define end states: The end state is when the three correct phrases are in the correct order;
  - Define state space: Tasks in Monsakun provide six sentences for the user. This means that three of the sentences are dummy sentences that won't be used. The dummy sentences are designed in a way that they violate their use will result in the violation of a specific constraint. The motivation for this is to make students must think about specific constraints to solve the problems. Another motivation is to be able to gather data on what constraints give student trouble. Given the six sentences, the search space for a Monsakun task contains 120 possible combinations.
  - Define initial state: All six sentences are available, and none are chosen;
  - Define feedback: Message telling users if their problem is correct or incorrect. Constraint-based feedback is also an option.

More information on the underlying structure of Monsakun can be found in the work of Hirashima et al. (2014).

4.2 Kit-build

Kit-build is a closed concept map building tool which was developed through the presented method. Further information on the design of Kit-build can be seen in the works of Hirashima et al. (2015). In Kit-build, learners build maps from provided pieces. The use of Kit-build has been associated with improved reading comprehension and with improved retention for contention. For example, the work of Alkhateeb et al. (2015) found that Kit-build users showed better performance ($M=79.06$, $SD=12.08$) in foreign language delayed comprehension test than traditional concept mapping users ($M=66.12$, $SD=20.26$) in an ANOVA test, $p < 0.01$.

- Original task analysis
  - Select subset of the original task: The subset of concept map construction we use in Kit-build is only making the connections using the links and nodes, without inputting the labels;
  - Define broad structure: The main structure in Kit-build is a concept map defined by the teacher. The map is made up of links and concepts.
  - Decompose structure: Maps are made up of multiple links and concepts. Links and concepts are treated as separate pieces which are not interchangeable.
  - Define constraints: The constraints in Kit-build are defined by the expert map designed by teachers. The constrains are the connections between the nodes and links;
- Gameplay design
  - Define goals: The overarching goal of Kit-build is to improve understanding of a text or class;
  - Define task: In a Kit-build task, users are tasked with associating concepts through links;
  - Define task-specific constraints: In Kit-build a node can only be associated to another node through a link. Furthermore, each connection in the expert map is a constraint of correctness. Violating these constraints would reduce the score of the map;
  - Define end states: There are two possible end states in Kit-build. One of them would be the student building the expert map. The other end state is the student building a map he is satisfied with. In the second case, even a submitted empty map would be a possible end state.;
  - Define state space: Assuming N nodes and L links, each link can connect two nodes. They can also be connected to no nodes at all. As such, the following equation defines the number of states in the space: $(N + 1)2L$
  - Define initial state: No links and no nodes are associated at first;
  - Define feedback: One automated feedback approach of Kit-build is based on showing the differences between the user map and the expert map back to the user, as in the work of Furtado et al. (2018).

5. Discussion and Conclusion

More research is necessary in gamification beyond reward-based systems. Core gamification refers to gamification methods that are more concerned with the internal design of the transformed activities. However, there is a lack of concrete method on how to perform core gamification of learning software. To address this, this work proposes a method of Core Gamification based on students manipulating information structures. Our proposed method addresses Core Gamification needs in the following ways:

- Actions
  - Actions serve to manipulate the information structure. They should be made clear by the interface design, employing intuitive and easy to use mechanics, such as drag-and-drop. Users will build or modify structures by using sets of pieces that make up the information structure. As actions are primarily used to modify these structures, every action is relevant to the learning target;
- Rules
  - The rules of gameplay are based on the intrinsic rules of the learning target, but clearly defined in terms of the information structure. As such, the rules of the gameplay are highly related to the learning target. This means that becoming a better player should imply in becoming a better learner. The large state space of the activities serves to discourage other learning behaviors that do not contribute to learning;
- Goals
  - The goal of the original activity is replaced with the goal of satisfying clearly defined constraints. These constraints are defined in terms of the information structure. They need to require understanding of the information structure to be solved. The constraints should be clearly specified to the players, so that their effort in solving the activities can go towards comprehending the information structure;
- Feedback

- Feedback is designed based on the constraints. A given state either violates or satisfies a constraint. As such, this information can be clearly shown to the player in the form of “correct” or “incorrect”. More complex feedback can be given by relating the information structure to reading material or by giving more detailed information on which constraints were violated and which were satisfied.

Evidence of the learning effect of applications that use this method has also been presented. This study presents, as far as researched, the first concrete method for designing gameplay of gamified applications.

For future work, the method will be expanded to include clearer interface recommendations. It is also necessary to quantify the effects of the applications regarding motivational metrics.

Acknowledgements

This work was partially supported by JSPS KAKENHI Grant Number 17H01839 and 15H02931.

References

Alkhateeb, M., Hayashi, Y., Rajab, T., and Hirashima, T. (2015). Comparison between kit-build and scratch-build concept mapping methods in supporting efl reading comprehension. *The Journal of Information and Systems in Education*, 14(1):13–27.

Brandt, R. (1995). Punished by rewards. *Educational Leadership*, 53(1):13–16.

Deci, E. L. and Ryan, R. M. (2002). *Handbook of self-determination research*. University Rochester Press.

Deterding, S. (2015). The lens of intrinsic skill atoms: A method for gameful design. *Human– Computer Interaction*, 30(3-4):294–335.

Furtado, P. G. F., Hirashima, T., and Hayashi, Y. (2018). Reducing cognitive load during closed concept map construction and consequences on reading comprehension and retention. *IEEE Transactions on Learning Technologies*.

Hirashima, T., Yamamoto, S., and Hayashi, Y. (2014). Triplet structure model of arithmetical word problems for learning by problem-posing. In *International Conference on Human Interface and the Management of Information*, pages 42–50. Springer.

Hirashima, T., Yamasaki, K., Fukuda, H., and Funaoi, H. (2015). Framework of kit-build concept map for automatic diagnosis and its preliminary use. *Research and Practice in Technology Enhanced Learning*, 10(1):17.

Hirashima, T., Yokoyama, T., Okamoto, M., and Takeuchi, A. (2007). Learning by problemposing as sentence-integration and experimental use. In *AIED*, volume 2007, pages 254–261.

Horiguchi, T., Imai, I., Toumoto, T., and Hirashima, T. (2014). Error-based simulation for error-awareness in learning mechanics: An evaluation. *Journal of Educational Technology & Society*, 17(3):1–13.

Jackson, S. A. and Marsh, H. W. (1996). Development and validation of a scale to measure optimal experience: The flow state scale. *Journal of sport and exercise psychology*, 18(1):17–35.

Lee, Y.-H. and Heeter, C. (2017). The effects of cognitive capacity and gaming expertise on attention and comprehension. *Journal of Computer Assisted Learning*, 33(5):473–485.

Mayer, R., Sternberg, R., and Freeman, W. (1985). Human abilities: An informationprocessing approach.

Nicholson, S. (2015). A recipe for meaningful gamification. In *Gamification in education and business*, pages 1–20. Springer.

Ryan, R. M. and Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist*, 55(1):68.

Susi, T., Johannesson, M., and Backlund, P. (2007). Serious games: An overview.

Wang, G. (2016). Game design for expressive mobile music. In *New Interfaces for Musical Expression*.

Yuan, M. and Shang, J. (2018). Values and design strategies of emotional design in educational games. *Proc. of ICCE2018*, pages 583–588.

Zeng, J. and Shang, J. (2018). A review of empirical studies on educational games: 20132017. *Proc. of ICCE2018*, pages 533–542.