Game Design as a Tool to Promote Higher Order Thinking Skills

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Abstract

This paper reports a study conducted on enabling teaching higher order thinking skills among kids aged 7 to 12 years old. The objective of the study is to propose a conceptual framework and demonstrate the tools and resources needed by educators to embed higher order thinking skills in classroom using game design. The conceptual framework is based on the standards advocated by International Society on Technology in Education (ISTE) and Computer Science Teachers Association (CSTA) that is mapped to the process of game design and development. Game design is an engaging process that encapsulates many tenets of thinking skills. The tangible outcomes and progress could be used to measure the thinking process and levels that had taken place. The paper then further demonstrates the use of this framework in a three day workshop. Two sessions of the workshop were conducted with a total of 44 participants. It is hoped that this study contributes in the areas of higher order thinking skills enablers.

1. Introduction

"The formulation of the problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill." - *Albert Einstein.*

The need to nurture thinking skills among students has been advocated by many scholars for many years. De Bono (1976) [6] has long ago suggested that the teaching of thinking skills may not be adequately achieved through the process of formal logic using principle and axioms. Cobb (1994) [19] recognised the need for students to construct their own knowledge and promote their thinking skills. Zoller (1999) [22] pointed that the development of higher order cognitive skills is essential to facilitate the transitions of students' knowledge and skill into responsible actions. Higher order thinking skills (HOTS) consists of problem solving, systemic environment and decision making as components [9][13][21].

The Revised Bloom's Taxonomy [14][17] placed analysing, evaluating and creating at a higher level of the cognitive domain in the learning taxonomy. In the taxonomy, analysing was defined as the act of separating material or concepts into component parts so that its organizational structure may be understood. It distinguishes between facts and inferences. The next level is evaluating where the student makes judgment on a particular idea. Creating, the highest level involves student putting parts from various elements together to form a whole to create new meaning or structure. Newman (1990) [7] stated that HOTS challenge the students to interpret, analyse or manipulate information.

The Malaysia Ministry of Education in its preliminary report on Malaysia Education Blueprint 2013 - 2025 released in 2012 has HOTS identified as one of the core skills to be focused in the first wave (2013-2015) [15]. It is stated in the blueprint that by 2016, higher order thinking questions will make up 80% of UPSR[1], 80% of the Form 3 central assessment, 75% of the questions for SPM[2] core subjects, and 50% of the questions for SPM elective subjects. This will refocus teachers' attention on developing HOTS. This is a remarkable goal set by the ministry. The question raises then is 'how can we teach HOTS in our classrooms?'. The average size of a classroom in a public school in Malaysia is 35 students. Public schools are attended by students from various socio-economy background. A classroom is typically heterogeneous.

This paper reports a study conducted to explore the use of game design and development as a platform to nurture HOTS. It is essential that this platform will provide an opportunity to learn skills related to higher order thinking and to ensure that they can be transferred to different problems and used in different contexts. The research question of this study is how do game design activities contribute in teaching HOTS? This study adapted game design activities ranging from low-threshold to high-ceiling activities so that students with no programming background can produce complete and exciting games in a short amount of time.

2. Is it possible to teach higher order thinking skills?

Atkins (1993) [16] mentioned that a learner learns more when the interactions between the learner and material are richer and comprehensive. Dede (1990) [5] suggested that HOTS as structured inquiry are acquired when:

1. learners construct knowledge rather than passively ingest information;
2. learners use sophisticated information gathering tools to be stimulated to focus on hypotheses rather than plotting data;
3. learners involve in collaborative interact with peers;
4. learners are measured for HOTS which is complex rather than simple recall of facts.

[1] UPSR - Ujian Pencapaian Sekolah Rendah: Primary school evaluation test conducted in standard 6. Students aged 12 years old. [2] SPM - Sijil Penilaian Malaysia: Secondary school evaluation test conducted in form 5. Students aged 17 years old.

Structure of Observed Learning Outcome (SOLO) model describes levels of increasing complexity in a learner's understanding of subjects [8]. The model consists of five levels in the order of understanding:

- Pre-structural - The learner doesn't understand/unsure of the lesson.
- Uni-structural - The learner comprehends only basic concept of the lessons and follows the procedure in his response.
- Multi-structural - The learner has several concepts about the lesson but they are disconnected.
- Relational - The learner has mastered the complexity of the subject by being able to join all the parts together.
- Extended abstract - The learner is able to create new ideas based on his mastery of the subject.

In a seminal article published in 2006, Jeanette Wing described computational thinking (CT) as a way of “solving problems, designing systems and understanding human behavior by drawing on the concepts fundamental to computer science.” [10]. She noted that computational thinking involves some familiar concepts, such as problem decomposition, data representation and modeling, as well as less familiar ideas, such as binary search, recursion and parallelization. She also argued “computational thinking is a fundamental skill for everyone, not just for computer scientists. To reading, writing, and arithmetic, we should add computational thinking to every child’s analytical ability.” The projects under ACM, NSF, ISTE, CSTA project has explored how students learn computational thinking at all grade levels and in all disciplines [20]. These skills include problem formulation, logically organizing data, automating solutions through algorithmic thinking, and representing data through abstraction. One of the ways identified on how students learn CT is through the use of game design [2][18]. Designing games has been shown to foster computational thinking [3], provide motivation for learning programming [1], and increase technological fluency [12].

3. Game design at the service of higher order thinking

This project advocates game creation as a teaching tool. Creating games is a process of ideation to realising it. Tangible outcome can be seen in this process. It is possible to measure on-going progress and final outcome. This provides a sense of purpose in the process of learning. Furthermore, the final outcome is a completed game with the intended content that can be tested and played by peers. This will provide an opportunity for sharing something that is made by the student himself.

A game is a systemic environment. Level of complexity could be adjusted according to time allocation. In this context, the gamification process serves as a mean for developing HOTS. As discussed in the previous section, HOTS could be used to nurture problem solving. Figure 1 shows how problem solving process is supported in the game design (and development) process. Basically, the activities in game design and development are used as scaffoldings in nurturing higher order thinking among kids. One of the key activities is to recognise the patterns at the subject matter level and at the game design itself. Once patterns and abstraction take place then the next step is to automate this by using computer tools i.e. game engines.

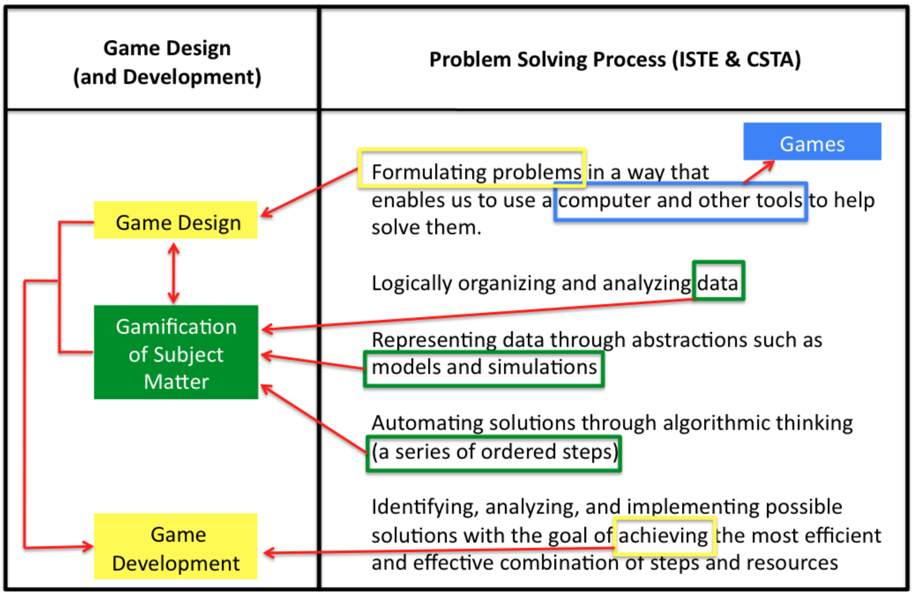

Figure 1 Using game design for HOTS framework

4.Implementation

A 3-day workshop was conducted for kids aged 7 to 11 years old under the Kids Game Lab project. The workshop was titled 'Introduction to Computational Thinking Through Game Design'. Two sessions were conducted with 22 kids per session. No pre-requisite was stated to participate the workshop. Call for participation was circulated within Multimedia University community. Basically, the participations were children of academic and non-academic staff of the university. The response towards the call was overwhelming. However, the capacity of each session was 22 students. The participants were chosen based on *first come first served*. The author was the only 'teacher' in the workshop sessions.

The workshop covered game design fundamentals which focused on the game elements and mechanics. Participants were then introduced to game design process using TRIZ pedagogy [4] as the framework for instructions. Formulation of the problem begins with teaching the participants 'how to ask questions'. Individual exercises were given to harness the game concepts and nurture HOTS. Figure 2 shows one of the exercises done on that day.

Figure 2 Example of game making exercise

The second exercise given was open-ended questions problem solving in groups. The objective was to introduce brainstorming as a process to identify possible solutions. The groups were given time to discuss, and each group was asked to present their ideas. Duplication of ideas was instructed to be noted by the other group rather than repeating it. This had increased the attentiveness among the participants towards what the other groups were presenting. During the brainstorming process, it was noted that extrovert personality participants dominated the discussion. To encourage better participation by introvert personality participants, the process was intervened by making it compulsory to take turns in the group to contribute. On top of the time constraint given, 'target' of 15 ideas was imposed, and groups with more than the target will win. This was done to add competitiveness element as a catalyst for more ideas to be generated. It was observed that this intervention was effective. All participants became active contributors throughout the course of the workshop.

The third exercise was also a group work exercise. The participants were given the task to design a game on any science content using the available resources provided on the 'Resources Table'. They were allowed to take anything in any amount from the Resources Table needed to make the game. However, penalty will be imposed for every unused resource. Participants quickly understood the need to plan first before going to the Resources Table. Gamification process took place as participants discussed, strategised and planned the content to turn it into a

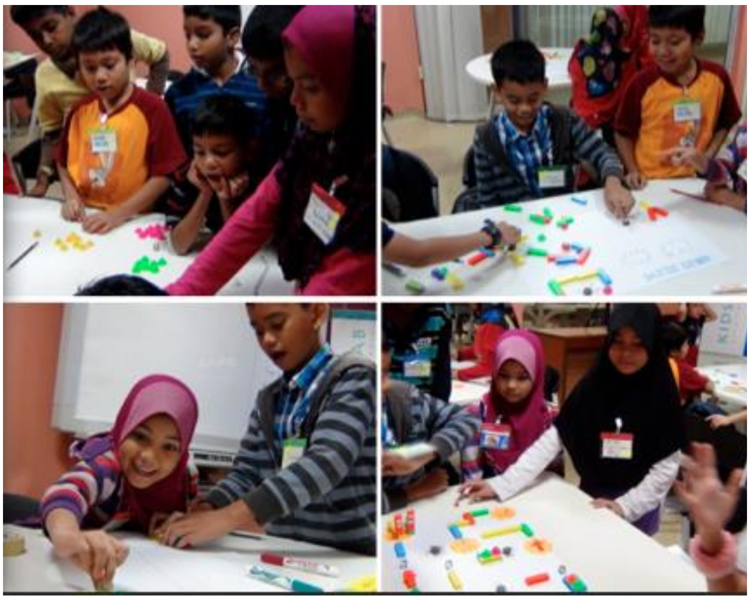

Figure 3 Science content game making exercise

game. It was also observed that active participations among all group members. The games created were then all tested by the other groups to rate the game. Participants were prompted to justify the rates given. This was an exercise to nurture ability to express thinking that had taken place. Inter-relationships between science content and the game mechanics were apparent in the thinking as observed in the justifications given. Figure 3 illustrates this exercise.

The workshop then advanced to digital game design and development on the second and third day of the workshop. The digital game design module uses the same game design fundamentals and elements from day-1. However, the fundamentals were mapped to the *input-process-output* of computer programs. Participants were ensured to grasp this concept. Again, TRIZ pedagogy were adopted in establishing a game as a systemic environment. In this exercise, game design process included *a series of ordered steps*. This exercise took place without computers yet. It was important that participants able to think through the process without the distractions of actually programming the game. Participants were given objects from the game making software that will be used as characters without them knowing it was from a software. The participants were then brought to the computer lab once everyone has presented their game design. The computer lab used in this workshop is a basic computer lab. Minimal computing resources were made important consideration to ensure this module is replicable in school classrooms. Microsoft KODU was used as the game authoring tool. Figure 4 illustrates the module taking place in the computer lab. Each participant worked on their own projects. At the end of the session, all participants presented their projects to the audience made of parents and faculty

Figure 4 Participants using Microsoft KODU

members.

5. Observations and discussion

Observations were made based on the dimensions suggested by Dede (1990) [5] on acquiring HOTS as structured inquiry and Biggs and Collis (1982) [8] SOLO model. Table 1 is a summary of observation made.

Table 1 Observation summary

Acquiring HOTS	Observations				
Active construction of knowledge	Construction of knowledge is observed through participation: Statements such as 'Oh! Now I get it', 'Oh okay', 'Why not?' are indicators of active construction of knowledge is taking place. 'A-ha' moments experienced by the participants were also observed. Usually, these moments came after a 'period of struggle' reflected through their anticipation, excitement, frustration and sometimes anxiety. This is observed during activities conducted whereby participants have access to the building blocks and required to do something out of the information relayed. Elaboration and justification given for ideas and decisions made in completing the activities. By verbalising thinking, it was possible to have an insight what and how participants were making sense of the information given and the activities that they were doing. Piaget (2001) [11] suggested that the reflection upon its own mental operation is the basis of reflective abstraction which yields all the important concepts that cannot be derived directly from sensory experience.				
Sophisticated information gathering tools to focus on hypothesis	The virtual environment used was Microsoft KODU. Participants explored the use of KODU through the help feature and online portal. Two approaches were observed: (1) I want to do this so how do I do it and (2) If I do this what would happen. The first approach yields a better outcome.				
Collaborative interaction	Exchange of ideas and opinion took place. In the beginning, it was observed that the most extrovert participants would dominate the interaction. Interventions were made to facilitate groups and sessions to enable for everyone to take part in the interaction. It was observed that once the introverts gained confidence to interact, the quality and liveliness of the groups increased. Examples of strategies found impactful were assigning designated roles, 'poison box', add/minus stickers as a group and group cheer. In the lab, the following were observed: Participants 'just knew' who among them are 'point of reference.' Willingness in helping each other out. Mutual exchange of know-hows.				
Measuring HOTS	Structure of Observed Learning Outcome (SOLO)				
	Pre - structural	Uni - structural	Multi - structural	Relational	Extended abstract
Final game output	Incomplete	Direct use of examples	Attempts to inject own ideas to the examples	Manipulation of examples	Cross-modification of examples

6. Conclusion

Game design is one of the tools that could be used in the classroom to promote higher order thinking. It is observed in this study that game design provides an opportunity to learn skills related to higher order thinking. Game design activities could be measured and observed for higher order thinking. It is also observed that participants with no programming background can produce complete and exciting games in a short amount of time.

7. Acknowledgement

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