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Inquiry Based Learning with Kanban Game

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***Abstract*— In this paper, we present the design and the effectiveness of a computer game that supports inquiry-based learning of Agile development with Kanban. Seventy four undergraduate students who were enrolled in classes related to software engineering participated in the study. By engaging students in multiple rounds of questioning and peer discussion, the students were actively involved in the conceptualization, investigation and generation of new knowledge. From survey results, observation of focus groups as well as the game log, we found that students were highly engaged in the learning process. There was also an improvement of students' knowledge in agile software development.**

Keywords—Educational Game; Game Based Learning; Agile Development

I. Introduction

There has been an increasing interest in the use of computerized simulation games to support the teaching and learning of engineering and business subjects. Game-based learning approach has been considered as one of the best ways to trigger students' learning motivation [1] and stimulate students' learning ability [2]. Studies have shown that the use of games improved students' engagement in the learning process and their perceived learning. There were a number of gamified systems and serious games developed for learning ISO 21500 standard [3], scrum [4], natural risk management [5], project management [6-9], search engine optimization [10-12] and digital marketing [13].

Agile development methodology helps companies accelerate software delivery, enhances their abilities to manage task priorities, increases their productivity and ensures product quality [14]. Due to the increasing popularity and adoption of agile practices in industries in the recent years, the teaching of agile methodology such as Scrum and Kanban is becoming an important part of the Computer Science and Software Engineering curricular. This paper presents development of a serious game and demonstrates its effectiveness in supporting the inquiry-based learning of agile software development. The inquiry-based learning approach has been widely used by education practitioners to meet the challenges and opportunities facing in the 21st century. It encourages learners to conceptualize a problem and figure out the solution and/or explanations to the problem [15].

In this paper, we present the design and the effectiveness of a computer game that supports inquiry-based learning of Agile development with Kanban. Game-based learning approach was considered a tool to achieve inquiry-based learning approach [16]. The paper is organized as follows. In section II, we review relevant literature. Related research studies are presented. The game design of our Kanban Game for supporting the inquiry based learning of agile development is presented in section III, followed by our evaluation of the game effectiveness in learning agile software development in section IV. Finally, the summary and future research directions are discussed in section V.

II. Literature Review

Thanks to the technological advancement, latest digital learning environment supports the inquiry-based learning approach. This is possibly one of the main reasons why inquiry-based learning has become popular in recent years [17]. Particularly, nowadays graduates are not only required to possess hard skills but also soft skills such as idea generation and critical thinking. The inquiry-based learning approach was proved to help students learn both creative and research skills [18]. Duran and Dökme [19] also found that the learning approach facilitate students' critical thinking. These skills are conducive to all-rounded development of fresh graduates.

An inquiry based learning cycle involves the following phases: orientation, conceptualization, investigation, conclusion and discussion [17]. The orientation phase aims to stimulate learners' curiosity about a topic or learning challenge through a problem statement. The conceptualization phase involves the generation of research questions and hypotheses based on the stated problems. The investigation phase involves exploration, experimentation, collecting and analyzing data to test a hypothesis or synthesis of new knowledge. In the conclusion phase, students draw conclusion and relate the simulation to the real world. Finally, in the discussion phase, learners present and evaluate their findings.

Many researchers have developed games or gamified systems to support inquiry-based learning. The results of their games were encouraging. Hwang et al. [16] developed a game for an elementary course of social studies. The game was developed on the basis of an inquiry-based learning strategy. The game was shown to facilitate game players' motivation, satisfaction, flow and learning achievement. Hwang et al. [16] also found that game-based learning through an inquiry-based approach is particularly suitable for learners of which learning style is more proactive. Sabourin et al. [20] developed a game-based learning environment named CRYSTAL ISLAND for microbiology course in middle schools. Their findings demonstrated that the gaming environment benefits learners who cannot effectively propose inquiries. The gaming environment encouraged learners of this kind gather information and subsequently become more capable in raising good inquiries and solving problems more effectively. Keneedy-Clark et al. [21] developed an inquiry-based game in science education. The game received positive feedbacks from teachers who played the game.

III. Game Design

Our Kanban game simulates an artwork asset creation workflow in a digital game development project. It aims to help students learn Kanban principles and its importance in agile development teams. In the game, artists (represented as paintbrush icons) are responsible for the design, create, review tasks, while Engineers (represented using screwdrivers) work on the test and deploy tasks. A Kanban board in the game shows the process that an artwork will go through, from design, create, review, test to deployment (refer to Fig. 1).

The game will start with the player pulling an idle artist to the assets (which look like small paintings) from the product backlog into the design column. Idle artists/engineers, those who are currently not working on anything, may take work-items from backlog/completed items, pull them to the next column and work on it. The assets are of various sizes to depict the different amount of effort required for each piece of work. Each item will have a bar to show its progress towards completion. Kanban imposes work-in progress (WIP) limit, where each phase will impose a limit on the number of items that can be "pulled" into that phase (shown at the top of each column). In the first round of the game, the WIP Limits for the various columns are pre-defined. Players can drag an idle resource to the completed items to "pull" it into the next column when there is enough capacity in the next phase to handle more work. The game allows swarming, where player may drag more than one engineer/artist to complete the work-item faster or resolve the issues more quickly and to get back to the normal flow.

In each round, players will be given six minutes to complete the work-items (artwork assets) in the backlog. The final score will be calculated based on the value delivered by time, where the value delivered is defined as items that are complete (by making it to the right side of the Kanban board). The work items are grouped by features with similar items of various size and the player can only get the score when all of the items that group together as a feature are fully deployed. There are random factors associated with the features' values, the effort required to complete the features, and the defects generated. Defects may appear in the review and test columns and it may take extra time to fix the defects and complete the work-items. The number of defects is random and not under the player's control.

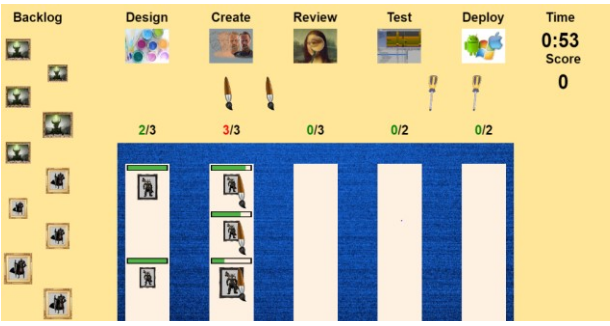

Fig. 1. Screenshot of the Kanban board in the game

A report (Refer to Fig. 2) will be shown at the end of the round to display the performance score (the amount of value delivered over time) and other metric such as resource utilization, the waiting time in each column, and the defects found in the game. The Cumulative Flow Diagram shows us the progression over time as items move across the board (Refer to Fig. 3). After reviewing the metrics, the player may adjust the WIP Limit (Refer to Fig. 4) for the various columns and start the next round of the game.

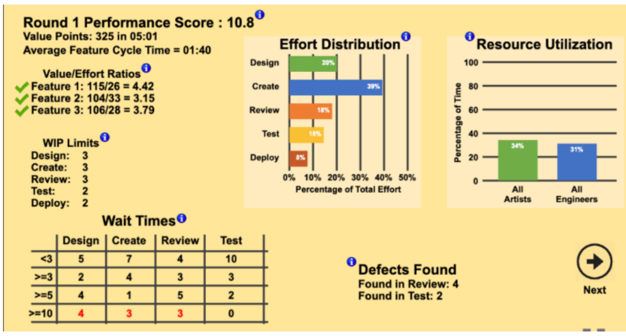

Fig. 2. Game report at round end

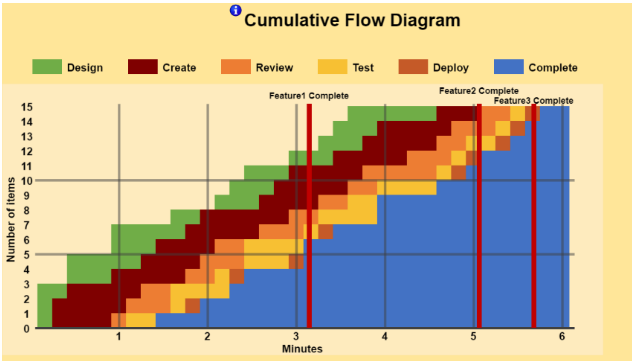

Fig. 3. Cumulative Flow Diagram (CFD)

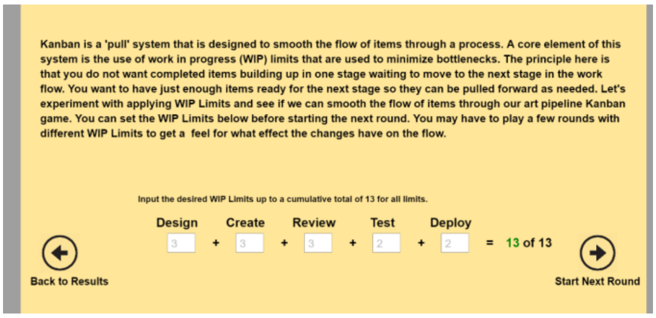

Fig. 4. WIP Limit Decision for the next round

IV. Evaluation and Results

A. The Study

Seventy four undergraduate students who were enrolled in classes related to software engineering participated in the learning study. Before playing the game, the students had learnt some basic concepts related to agile development (such as Scrum) in previous lectures. However, the Kanban methodology or related concepts had not been introduced to the students.

Each game-based learning session lasted for 3 hours. During the learning session, the lecturer first gave a brief introduction of the game. The students were then required to fill out a pre-game knowledge test and a pre-game survey. Table I shows some sample questions of the knowledge test. The pre-game knowledge test assessed the students' initial knowledge of Kanban. The pre-game survey collected some background information of the students.

After the game introduction, the students started playing the game. They were reminded to learn from the hints and information related to the different Kanban metrics provided in the game. After the first round of the game, the student were encouraged to discuss the general feelings towards the game scenario, observations about the game, and their game strategy in the game. The lecturer then conducted a 10-minute in-game debriefing to review the various metrics/charts in the chart and the WIP limit concept in Kanban.

After that, the students played the second round of the game which was followed by a second round of discussion. This round of discussion focused more on more in-depth issues related to the different aspects of the game (e.g. lead time/value delivered, randomness, bottleneck, waiting time, WIP limits). The students then played the game the third time, and then participated in the third of discussion that focused on generalization and connection of the game to the real-word Kanban and software engineering practices. Sample topics of the discussion in the three rounds are shown in Table II. By encouraging the students to raise more inquiry about the subject contents, we expected that the students could proactively generate new knowledge from the game.

At the end of the game-based learning session, the students were asked to complete the post-game survey. Questions of the post-game survey were adapted from relevant literature such as [22], [23] and [24]. Finally, a short post-game debriefing session were conducted by the facilitator (i.e. the lecturer) to review the lessons learnt from the game, followed by the post-game knowledge test (with the same set of questions as the pre-game knowledge test) to evaluate the students' improvement in understanding of the subject content after playing the game.

TABLE I. SAMPLE QUESTIONS OF KNOWLEDGE TEST

Questions	
Q1	Kanban is a push-based system (True/False/I Don't Know)
Q2	WIP Limits should be decreased ahead of a bottleneck (True/False/I Don't Know)
Q3	The Kanban system is designed to increase resource utilization (True/False/I Don't Know)
Q4	A cumulative flow diagram (CFD) shows WIP over time (True/False/I Don't Know)

TABLE II. SAMPLE QUESTIONS FOR IN-GAME DISCUSSION

Round	Questions
I	- What strategy you have adopted when playing the game? - What strategy have worked and what didn't work? - How is your game performance compared with other students? - What will you to do next time to improve the game performance?
II	- How many features can you complete? What is the feature lead time? What is the value delivered? - How do you set the WIP limit? Why? - What have you observed that is random and you cannot control in the game? What do you feel about them? - Where is the bottleneck in the artwork pipeline? How do you identify the bottleneck? How do you deal with the bottleneck? - Are there idled tasks/work-items? How can you reduce the waiting time?
III	- What is your strategy in setting WIP Limit? How does it affect the game performance? - What are the types of defects which may appear in the artwork pipeline? What will you do to reduce defects? - What is the difference between the game and the real world?

B. Results

The average scores from the pre-game and post-game knowledge tests are shown in Table III. The results show that students have better understanding of the Kanban knowledge after the inquiry-based learning with the Kanban Game. The post-game survey results are summarized in Table IV. Overall, the game received positive feedbacks from the students. Particularly, the students perceived that the game-based learning session is useful (m=5.43, sd=1.16), makes them feel joyful (m=5.4, sd=1.25), makes them curious (m=5.25, sd=1.27) and intend to use the game again in the future (m=5.25, sd=1.26).

In addition to self-reported measures, we also examined the log of the game. We intended to think that the engagement levels were significantly higher than in a typical lecture format class. Before the game-based learning session, we expected that the students would play around 3 to 4 rounds. However, it turns out that the majority of the students played more than 4 rounds. One student played a total of 28 complete rounds. This shows that the students likely enjoyed the game and continued playing beyond what was required in the class. During the in-class discussion sessions, the students were very active in discussion with the facilitators during the class.

TABLE III. SCORES OF PRE-GAME AND POST-GAME KNOWLEDGE TEST

	Scores of Knowledge Test
Pre-test	3.89
Post-test	4.67
Change	0.78

TABLE IV. CONSTRUCTS MEASURED IN THE POST-GAME SURVEY

Construct	Ratings (From 1 to 7)
Joy	Mean = 5.4; SD =1.25
Control	Mean = 4.74; SD = 1.52
Curiosity	Mean = 5.25; SD = 1.27
Ease of Use	Mean = 4.59; SD = 1.68
Focused Immersion	Mean = 4.27; SD = 1.56
Temporal Dissociation	Mean = 3.76; SD = 1.8
Challenge	Mean = 4.77; SD = 1.6
Skill	Mean = 4.32; SD = 1.56
Usefulness	Mean = 5.43; SD = 1.16
Intention to Use	Mean = 5.25; SD = 1.26

C. Focus Group

Eight students who have played Kanban game were invited to participate in two sessions of focus group. The focus groups aimed to study the students' learning experience in the inquiry based learning process with the Kanban Game. The qualitative analysis helped us further capture understanding of learners' game experience that cannot be easily shown in quantitative surveys.

Two of the participants mentioned that they were motivated to play the game because they found that their scores were lower than the other players. As a result, they kept playing the game repeatedly and try different strategies in the hope of getting better gaming performance. They felt that the game is exciting because of the limited time provided in the game and they liked the game because the game duration was short. They could know about the improvement opportunities very quickly. The timely feedback of the game was considered a plus.

The participants were also asked about the peer discussion between the rounds. They mentioned that they have discussed the game strategy (e.g. the way to set the WIP limits of the different phases) and there were some discussion about the different metrics and charts in the game. Two of the participants mentioned that the discussion makes the game playing process more interesting.

Nevertheless, we also noticed some room of improvement. Some participants felt that it could be too rush to complete the three rounds of game and discussion within the 3-hour period. Overall, the majority of the students' discussion during the gaming process focused on the game strategy. However, there were relatively less in-depth discussion about the game metrics and concepts behind the Kanban game. Some of the students found it difficult to link up the game with the learning objectives. Moreover, the participants raised the concerns that the drag and drop game mechanics is a bit repetitive, and they felt tired after playing the game multiple times.

V. Summary and Future Research

In this paper, we presented an effective computerized serious game for inquiry-based learning of agile development with Kanban. From the survey results, focus group observation and the game logs, we demonstrated that the students were strongly engaged in the learning process and there were improvement of knowledge. The engagement facilitates students' conceptualization, investigation and generation of new knowledge through the game.

Based on the feedback from the focus group sessions, we also identified a number of challenges. First, when compared with traditional teaching approaches such as lecturing and case studies, more time is required for students to get familiarized with the game before students may learn and generate new knowledge from the game. More time should be provided for game playing and discussion to give the player enough time to process the new information. Also, the game design can be improved to better facilitate the inquiry-based learning process. For instance, more details about the game metrics can be provided to the students in multiple screens/stages to facilitate students to learn progressively from the game.

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