# A Challenge of Developing Serious Games to Raise the Awareness of Cybersecurity Issues

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## ABSTRACT

One of the Japanese Government Reports says that there are about 265,000 persons in charge of cyber securities in our country, but we need to raise more 80,000 persons. In order to solve this problem, many companies and schools are providing educational programs, but lecture types of learning is not enough effective since the methods and techniques of cyber attacks drastically grow day by day. Therefore, our proposal is to introduce "Serious Games", and here are three reasons to support it. One reason is that since games are attractive to many persons in Japan, they would be good learning materials to keep their motivation. The other reason is that games are good method of simulation based learning and training for dynamically changing cyber security issues. The last reason is that computer games are the good platform to perceive the learning activities of person, and to continuously update educational materials by updating software contents.

With this aim in mind, on April 2014, we have organized an Executive Committee (ExCom) of Serious Game Jam (SGJ) consisting of members from academia and industry. A Game Jam is known as an effective method to develop prototypes of game in a short term, and about 60 university students who are majoring in computer science or game developing attended to the Serious Game Jam for Cyber Security (SGJ#2). They have proposed 42 games, and 6 were developed in two days. Out of those 6 games, 3 games have been tuned after the SGJ, and we have evaluated 3 games in three experiments by 152 (take#1: 61, take#2: 23, take#3:68) university students. Through those experiments, we have confirmed the effectiveness of serious game for cyber security education, and also obtained the implication of future possibilities. In this paper, an overall activity of this challenge, experiments, results and lessons learned are described.

## Keywords

cyber security education, serious games, game jam, targeted email attacks

**Proceedings of DiGRA 2019**

## INTRODUCTION

Given the increasing number of cyber attacks, it has become more important to provide education and training for more persons on this topic in Japan. As we have stated in the abstract, one of the Japanese Government Reports says there are about 265,000 persons in charge of cyber securities in our country. However, because of the remarkable progress of attacker's skill and technology, their knowledge and ability to defend cyber attacks are not enough, and we need to raise more 80,000 persons for cyber securities.

Although many of the companies and schools are providing educational programs for cyber security, lecture type of learning is not satisfiable since the methods and techniques of cyber attacks drastically grow day by day. Therefore, our proposal is to introduce "Serious Games", and the followings are the reasons to support this idea.

(1) Computer games are attractive to many persons in any generation in Japan, therefore, serious games might be effective to increase and keep the motivation of them for learning.

(2) Serious games are good method of simulation based learning and training for dynamically changing world, and cyber security issues are typical such subject.

(3) Serious games are the good platform to perceive the learning activities of person, and to continuously update educational materials by updating software contents.

Although serious games seem good solution, we need to spend much time for the development and evaluation to show the effectiveness. In order to shorten the development time, Game Jam is known as a good method to develop various types of games in short time, usually several days. Moreover, developing serious games is also good for learning that subject. Therefore, we have decided to develop serious games for cyber securities with university students, and evaluate the effectiveness by applying developed serious games to students.

With this aim in mind, on April 2014, an Executive Committee (ExCom) of Serious Game Jam (SGJ) was organized, consisting of members from academia and industry, and we have named the Serious Game Jam for Cyber Security event as SGJ#2. We have promoted this event to several universities, and about 60 students who are majoring in computer science or game developing attended to this Game Jam event. They were given half day training course on cyber threads on May 11th, especially focused on targeted e-mail attack, and they have made 42 proposals by the end of May. 6 proposals out of 42 were selected by ExCom for development, and they were developed on June 28th and 29th.

After the event, 3 serious games out of 6 continued to be tuned until September, and the effectiveness experiments were performed at three different universities from October to December. In total, 152 students joined this experiments and the effectiveness of serious games were achieved.

In the following sections, we will describe the overview of this challenge, the results, experiments and also implicate the future development by showing the lessons learned.

## SERIOUS GAMES AND GAME JAMS

The term “Serious Games” first appeared in a book written by Clark C. Apt (Clark C. Apt, 1970). In that book, he mentioned that game is effective for education and training, and named such games as Serious Games. It was written just before the computer games or video games became popular in the market. As the advancement of computer and software technologies, computer games become widely popular, but most aimed entertainment purposes.

At the same time, the development of simulators and simulation systems for defense, space and aeronautics industries pushed the technology advancement of computer and computer games. In those fields, those systems were called Modelling and Simulation (M&S), and used for education, training, exercise support and strategic planning support. It has been known that both game and M&S uses same key technologies such as CG, AI, VR and others, and researchers are overlapped, but the different industries has been in charge for game and M&S until 2004.

In 2004 at the GDC (Game Developers Conference), which were known as an entertainment game developer’s conference started to open a “Serious Game Summit”, and the name of “Serious Game” become popular. After that, many serious games have been developed in many fields.

In technological point of view, entertainment game and serious game are both same computer games, and the difference is the purpose. The term serious means if it is aimed to solve the problem in the real world or not, such as to improve the skill or knowledge, rehabilitation, medical treatments, training and education. Although M&S takes an important role in such field, it does not means that serious game is equal to M&S, since serious games does not always models the real world.

A variety of serious games for education have been developed, and “Making History (MH)” is one of the known one and it is used at high school to support history classes (Willian R. Watson et al., 2012). In MH, players act as the president or prime minister in the World War Second years, and they gather and hold the world situation to consider the next strategies and decide the policies to overcome the situation. During this process, students can learn the modern history of the world.

The other one is Brain Age (BA) which is very popular not only for young persons but also for elder people for brain training type educational game. BA was developed in Japan, and it has been expected for elderly persons to protect from the senility by activating our brains using games. The effectiveness experiment was performed for BA (Nouchi R. et al, 2012), and they have divided into two groups, and one use BA and the other use Tetris game, and did experiments to compare the performance of cognition and other functions between two groups. The results showed that BA has showed the partial effectiveness, but they also mentioned that it is too early to say the effectiveness of BA for all cognitive functions of humans.

In the field of cyber security education and training, CyberNEXS has been developed and widely used for training cyber defense for high school and university students in the US (Nagarajan A. et al, 2012). They can learn not only cyber security knowledge but also more on defending skills specialised in computer network defense, forensics and capture the flag. Although CyberNEXS is somewhat de fact standard in cyber defense competition, and widely used among students in the US, the applicability of this system for adults or children in general is not shown yet.

There is another integrated serious game platform for cyber security called CyberCIEGE (B.D. Cone et al, 2005, C. E. Irvine et al, 2005, J. Jones et al, 2010,

Raman R. et al, 2014). Since it consists of a game browsing tool with 3D office environment and characters, integrated with a scenario development tool, instructors such as teachers can develop their own serious game. In a study in India, CyberCIEGE was used for cyber security concept learning material, and the experiment done for 20 graduate engineering students showed the effectiveness of using serious game (Raman R. et al, 2014).

Although the serious games shown above can partially solve our problems (raise more 80,000 persons for cyber securities), we need to have serious games for various levels of learning objectives and for many types of persons in general. As the Bloom's Taxonomy (B.S. Bloom, 1956) shows, learning objectives are described in 6 levels of learning in pedagogical structure. It implies that one serious game cannot cover all levels. Therefore, we have started to discuss the importance and necessity to obtain various types of serious games to solve our problem. Through our discussion, Game Jam method of development was finally proposed to challenge.

Game Jam (Turner Truna et al, 2013) is known as a small game development events and GGJ (Global Game Jam) is one of the largest annual event that started in 2008. From 2009 to 2012, GGJ was a project of IGDA (International Game Developer's Association), and it has been managed by Global Game Jam, Inc. from 2013 (Global Game Jam, 2019). In 2014, more than 23,000 persons from 72 countries participated and 4,292 game projects were registered (developed). Game Jam is not only an event to develop games in short period, but also regarded as an efficient method for prototyping new software product (Musil, J. et al, 2010, Goddard William, et al, 2014). Recently, a Game Jam method was introduced to develop serious games for healthcare (Preston Jon A. et al, 2014).

## SERIOUS GAME JAM

In April 2014, we have organized an Executive Committee (ExCom) of Serious Game Jam (SGJ) . Since one of the ExCom members organized a Serious Game Jam for English Learning in Feb. 2014, we have named this Serious Game Jam for Cyber Security as SGJ#2 (Second Serious Game Jam). In the following, we will describe the overview of this Serious Game Jam in chronological order.

**April 2014:** ExCom of SGJ was organized. Then ExCom has discussed the target use and learning objectives as follows.

Learning subject: Basic knowledge about cyber security, specially focused on targeted e-mail and defending skills for them.

Learning objective (based on Bloom's Taxonomy): Knowledge level with basic comprehension level.

We have promoted this SGJ#2 event to several universities, and about 60 students who are majoring in computer science or game developing showed their intention to attend. In order to explain the learning objective and the subject, we had a half day special lecture course on May 11th.

**May 11th, 2014:** A half day special lecture course was held in Tokyo, and about 60 students of six universities attended. In the lecture, we have asked a specialist to talk about the current trend of targeted e-mail attack and basic knowledge of cyber security. From this day until the end of May, students prepared for pera-con ("pera" is a proposal written in one sheet, and "con" is an abbreviation of contest) .

**Figure 1:** Special lecture of targeted e-mail attack held on May 11, 2014

**May 26th, 2014:** Pera contest was held at Nihon University (NU) and Tokyo University of Technology (TUT), 43 peras were presented and 6 listed in Figure 2 were selected as development. In the figure, the title of the games is listed from left column top to bottom, then right column.


**Figure 2:** 6 peras selected as development

(1) Mail Stock Farm Story, (2) Security Night, (3) Virtual Adult Matching Service - Targeted Mail Prevention -, (4) Security Growth, (5) The Multi-tasking, (6) Receive a promotion

From this day until the end of June, students organized groups to develop 6 serious games, and they have used this period as a preparation phase.

**June 28th ,2014:** Day 1st of the serious game jam and it was held at NU and TUT. 1st day started from 09:00AM and ended at 06:00PM, and both were connected through Skype to share the same atmosphere.


**Figure 3:** Day 1st of the serious gam jam at two places

**June 29th, 2014:** Day 2nd of the serious game jam, and it was held at a cafeteria space of a company in Tokyo. About 40 students from 7 universities (Nihon Univ., Tokyo Univ. of Technology, Tokyo Polytechnic Univ., Tokyo Zokei Univ., Kanagawa Institute of Technology, Waseda Univ. and National Defense Academy) joined, and they have developed and finalized their serious games from 9:00AM to 03:00PM. From 03:00-04:00PM, final presentation and award ceremony was held.

**Figure 4:** Day 2nd of the serious game jam in Tokyo

**July to September, 2014:** In order to evaluate the effectiveness of serious game, we have asked students to refine and tune their games. Over the summer holidays, two of the serious games (5 and 6) were merged into one game, and other two (1 and 4) continued to be completed development and they are listed below.

A) Mail Stock Farm Story ("Mail Bokujo Monogatari")

The player is asked to perform as an owner of stock farm, and an objective is to grow the farm by properly feed sheep who eats paper made mails. The task of the player is receiving mails, and asked to classify good mails and bad mails. Properly classified mails can be given to sheep to grow them, but unproperly worked one slims the sheep. The player sells grown sheep to make money, and can get more sheep to grow the farm (Fig. 5).

B) Security Growth

The player is asked to perform as a boy who likes a girl named "Yui-chan". The objective of this game is to be good friends with Yui-chan by learning more on cyber securities and defending targeted e-mails. The player gets money and saves by doing good job. When he save enough money, he can date with Yui-can. However, when he performs bad, she becomes sulky and their friendship might be broken (Fig. 6).

C) The Multi-tasking – Receive a Promotion! – (“The Multi-tasking -Nariagare!-”)

The player is asked to perform as a woman who is a newly employed trainee at a company. Everyday work at a company is based on e-mails, and she has to process a bunch of e-mails of which some of them are targeted e-mails, and the score will be increased when she performs well. In some mail, meeting schedule is informed, and she has to attend the meeting, while she is processing e-mails. The game simulates the office work based on multi-tasking, and player can take and promotion exam to be a manager, general manager and so on (Fig. 7).


**Figure 5:** Mail Stock Farm Story


**Figure 6:** Security Growth


**Figure 7:** The Multi-tasking –Receive a Promotion!- (-Nariagare-)

**October to December, 2014:** Three experiments for effectiveness tests were conducted. In total, 152 university students majoring engineering, arts and social science cooperated these experiments, and it was done in three phases. In take #01 phase, 61 students were divided into four groups, the first group is to play serious games, the second group is to learn using e-learning tool, the third group is to learn with written materials and the fourth group do nothing above. In take #02, 23 students joined, in take #3, 68 students joined and all played serious games. The evaluation methods and results will be shown and discussed in the next section.

## EVALUATION

In order to evaluate the effectiveness of the serious games, we had three phases of experiments (Take #1, #2 and #3). In total, we had 152 volunteer students who are from three universities, and we have divided them into 6 groups for experiments (Fig. 8).

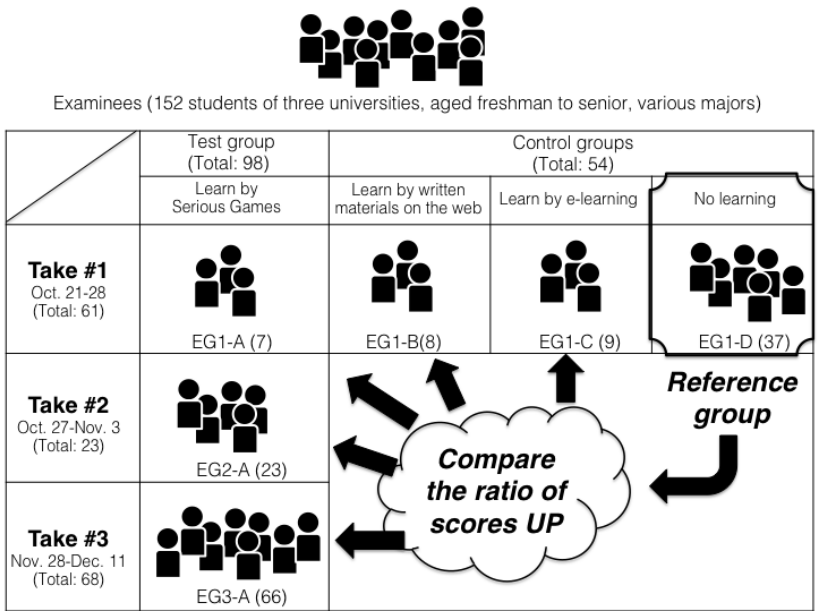


**Figure 8:** Test group and control groups for experiment

The main objective of Take #1 was to have the basic information about 4 different groups, and we could obtain standard data for reference group, which means that how the ability of students change or not change when they do not learn. We also had reference data for students who learn by written materials, and also learn by e-learning system. In this experiment, we have used Moodle as an e-learning tool (Rice, W. et al, 2008). Take #2 and Take #3 were conducted to get effectiveness data for more number of examinees. Although the number of days for experiment differs for each takes, total time that we have asked for examinees of group A,B and C is same, at least 4 days, more than 20 minutes per day.

In order to measure the change of performance on the knowledge about cyber security of the examinees, we have prepared two sets of quiz, Type A and Type B. The both of Type A and Type B quizzes were made by a specialist of cyber security, and some of the questions were based on the Information Technology Engineers Examination (ITEE) which is being operated by the government. Those quizzes have 25 questions and it takes 20 minutes to complete. Choice of Type A or B depending on the group of the examinees. We used Type A as before the game quiz for Take #1 and #3, and

we used Type B for Take #2. Although the difficulties of the tests were almost same, we have used standard deviation score for evaluation which is shown later.

On the first day of the experiment, all examinees were informed about the experiments, then took ether of the quiz on that day, except some examinees who could not have time on that day, they could took on the following days. Experiment took 8 days or 14 days depending the groups, but their obligation to play games or other tasks for group A, B and C was to do them at least 4 days, and we did not set maximum limitation.

**Table 1:** Mean raw score of before and after quiz and standard deviation

| Mean raw score (full score = 25) | | Test group | Control groups | | | SD |
|---|---|---|---|---|---|---|
| | | A | B | C | D | |
| BEFORE | Take#1 EG1 | 18.29 | 18.00 | 18.56 | 18.81 | 6.24 |
| | Take#2 EG2 | 16.31 | | | | 3.03 |
| | Take#3 EG3 | 16.90 | | | | 10.76 |
| AFTER | Take#1 EG1 | 19.29 | ***17.38*** | 18.56 | ***16.22*** | 3.31 |
| | Take#2 EG2 | 19.48 | | | | 2.38 |
| | Take#3 EG3 | ***16.41*** | | | | 18.86 |

Table 1 shows the mean raw score of before and after quiz and the standard deviation. As the table shows, the mean raw score of Take#1 EG1-B, EG1-D and Take #3 EG3-A became worth in after quiz. However, it does not mean that serious game for group EG3-A and written materials for group EG1-B was not effective, since there are students that the score increased in the after quiz.

Table 2 shows the number of person whose raw score of after was better than before. The ratio of EG1-D is 24.32%, and this is the reference. All other groups got better ratio than that reference. Especially EG1-A and EG2-A got 71.43% and 69.57% respectively. However, we can read 36.76% for EG3-A, and it is lower than that of EG1-B (written material) and EG1-C (e-Learning), which sounds the effectiveness of serious game is lower than that of conventional learning method. However, since Table 2 shows the raw score, we should more focus on the standardized score. Table 3 shows the number of persons and ratio based on deviation score.

As the table 3 shows, the result of EG3-A (45.59%) is better than both of EG1-B (37.50%) and EG1-C (44.44%) by analyzing using a deviation scores. This result shows that the serious games was effective to all groups (EG1-A,EG2-A and EG3-A) for university students.

**Table 2:** Number of persons and score UP ratio based on raw score (>0)

| Number of persons and ratio raw score UP(>0) | Test group | Control groups | | |
|---|---|---|---|---|
| | A | B | C | D |
| Take#1 EG1 | 5<br>71.43% | 3<br>37.50% | 4<br>44.44% | 9<br>**24.32%** |
| Take#2 EG2 | 16<br>69.57% | | | |
| Take#3 EG3 | 25<br>***36.76%*** | | | |
| Total | 46<br>46.94% | 3<br>37.50% | 4<br>44.44% | 9<br>24.32% |

**Table 3:** Number of persons and score UP ratio based on deviation score

| Number of persons and ratio deviation score UP(>0) | Test group | Control groups | | |
|---|---|---|---|---|
| | A | B | C | D |
| Take#1 EG1 | 5<br>71.43% | 3<br>37.50% | 4<br>44.44% | 9<br>**24.32%** |
| Take#2 EG2 | 13<br>***56.52%*** | | | |
| Take#3 EG3 | 31<br>**45.59%** | | | |
| Total | 49<br>50.00% | 3<br>37.50% | 4<br>44.44% | 9<br>24.32% |

Table 3 shows the overall effectiveness for group A (98 students in total), and it is 50.00%. It means that serious game was effective to half of the students, and we can conclude that the relationship between the effectiveness of learning methods is as follows.

***Serious Game > E-Learning > Written Materials > No Learning***

## DISCUSSION

In the previous section, we have shown that serious game was effective in learning cyber security, and about 50% of the university students could raise their score. In this section, we would like to discuss how we could increase the effectiveness.

Fig. 9 shows the correlation between the days examinees played and the deviation scores. From the graph, we can read that both correlates for EG1-A and EG1-B, but not for EG3-A. We have more deeply analyzed their behavior log of EG3-A, and we have found that some of them did not take the after quiz properly. Two persons who have played the game for seven days (marked in a square box at EG3-A of the figure), and who got -15 and -11, they have spent only 1 min 49 seconds and 1 min 15 seconds respectively to take that exam. Since there were 25 questions in a quiz and it was designed to solve it in 20 minutes, we can guess that those two students did not take that quiz properly. Moreover, according to the questionnaires that we have taken at the end of the experiments, both persons answered that “Those serious games were not fun”, “Fun is mandatory to serious games”.

According to the results of the experiments and the discussion, we infer the followings.

1） Serious games that we have developed were effective, since the ratio of score UP 50.00% was higher than that of the control group (no learning) 24.32%.

2） Serious games that we have developed were more effective than other learning method such as written material (37.50%) or e-learning (44.44%).

3） Serious games that we have developed were not effective to some students who did not think they were fun. As it is same to the entertainment games, single game does not satisfies or attracts all users. Therefore, we need more studies of the three developed serious games, as well as other serious games to enhance the effectiveness to more persons.

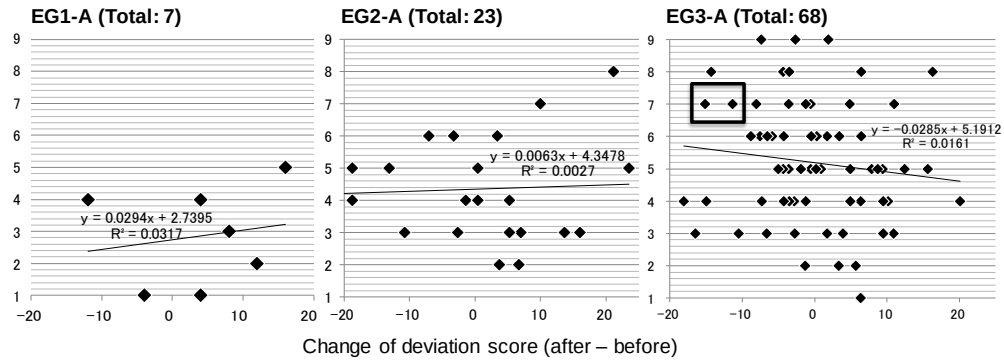


**Figure 9**: Correlation between the days played and the deviation score

## CONCLUSION

In this paper, we have presented our challenge to raise the awareness of cyber security issues by developing serious games using Game Jam method. The Game Jam method was effectively contributed to derive 42 serious games ideas in short term (about 3 weeks), and could develop 6 serious games in two days, excluding about one month for preparation.

As the experiment results show that three serious games were effective for university students in raising the knowledge about cyber security in 8 to 14 days. Although we could infer that they are effective in overall, we could also found that they were not effective to all students. The main reason for this is that those games were not fun for some students. In order to make it clear, we need to study more about how to measure the fun of serious games. The results also showed that they were more effective than that of other learning methods such as using written materials or e-learning. However, since we used them just as a reference to compare in this study, more to be studied for those issues in the future.

In Sep. 2014, Ministry of Defense of Japan has announced a budget for 2015 FY to be used on cyber security serious game issues and this movement of introducing serious games to their education and training purpose is expanding, and we think that our activity of organizing Serious Game Jams took an important role.

Following the 2nd Serious Game Jams, the event became an official Game Jam of DiGRA JAPAN chapter, and we have been conducting SGJ3 in Feb. 2015, SGJ4 in Feb. 2016, SGJ5 in Dec. 2016, SGJ6 in Dec. 2017 and SGJ7 in Dec. 2018. Moreover,

we have started to exhibit some of serious games developed at the latest Serious Game Jam at Tokyo Game Show 2018 and Taipei Game Show 2019, respectively. We wish our activity of organizing serious game jams in Japan to stimulate exploring the new market of game industry in Japan.

## ACKNOWLEDGMENTS

This research could not be done by the support of ExCom (Executive Committee) members of Serious Game Jam. We thank Prof. Kishimoto, Prof. Ide, Prof. Mikami, Mr. Ono, Mr. Miyata for their work as ExCom as well as providing their insight and expertise that greatly assisted this research. We would also like to show our gratitude to all the attendants of this serious game jam and anonymous supporters who have used our serious games for evaluation. We also would like to give special thanks to DiGRA JAPAN for their continuous support for the following serious game jams (SGJ3 – SJG7).

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