A Case Study on Learning Effectiveness of Information and Communication Security

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Abstract
In recent years, incidents related to information and communication security have been very common, therefore the reinforcement on education of information and communication security and the training of its professionals have become very important. Nevertheless, it is not an easy job to develop such professionals due to the great diversity in information and communication security field. Many experts and specialists believed that good teaching materials will facilitate educating and training of professionals. Unfortunately, traditional teaching materials on information and communication security are mostly based on theories, tools and skill development and lack elements of interesting design for stimulating learners’ self learning desires and guidance. Learners lose interests and confidence easily because the teaching materials are too difficult to inspire their learning motivation. Digital game-based teaching materials are considered effective on promoting the learners confidence and learning motivation. This research constructs a teaching material for educating information and communication security that allows a user to learn with the speed and contents according to his or her own need. A case study also conducted in this paper. It shows that digital game-based teaching material efficiently promotes the learning effectiveness.

Key Words: Information and Communication Security Teaching Materials, Digital Game-based learning, Adaptive Remedial, Self-learning Material Design

1. INTRODUCTION

1.1. Background and Motivation
With the rapid development of internet, the computer and internet are closely tied together with our lives and works; in the meantime, cybercrime is also getting rampant [10]. Therefore, problem and education related to information and communication security have increasingly become important issues. 2008 Information and Communication Security Policy White Paper published by Science and Technology Advisory Group, Executive Yuan in 2008 had revealed the vision [13] of “a secure and reliable information society and secure and high-quality digital life”; moreover, in the second phase, the education of information and communication security talents and the deepening of the cognition and education of information and communication security were the implementation focuses [10, 20, 21]. Due to the broad width of information and communication security, it is not easy to develop talents of this field. Besides, in TANET 2009, our standing vice-minister of MOE (Ministry of Education) Wu Tsai-Shun mentioned that it needs information and communication security education to solve
the problems related to ethics and moral of information and internet. Lots of experts and scholars regard that information and communication security teaching materials will facilitate the development of these talents.

Nonetheless, traditional information and communication security textbooks are mostly based on the teaching framework of theory, tool and skill and compiled according to authors’ own teaching experiences, and they generally lack the guidance of self learning [24] and instructional design. General learners’ learning effectiveness comes mostly from the reading of teaching materials and partly from teachers’ instruction and doing experiment; for number theory courses which take highly-cognitive concept or some difficult information and communication security courses, if learners are unable to understand them successfully, then they might have resistance to learn and will stop learning. Consequently, some scholars started to suggest improving the circumstance by using digital teaching materials. However, most designs of digital information and communication security teaching materials are hierarchical, divided by chapters and one-way learning without interactive learning [9, 11, 17]. They do not make learners to absorb and internalize knowledge successfully, and hence it caused some difficulties in the promotion of information and communication security education.

1.2. Research Purpose
Self-learning teaching material design and virtual reality simulation will help learners to do thinking actively, apply related concepts, reinforce reflection, connect knowledge, use the skills accordingly, promote learning effectiveness and achieve the original teaching goal [7, 22, 23]. Game-based learning reflects and produces a virtual environment [1, 14] through the medium such as character, sound, image, and animation, and it provides learners with an experiential and participative learning environment. The integration of games into information and communication security course allows learners to grope and practice repeatedly through games and to grasp skills they want to learn and intricate concepts and knowledge through the formative evaluation in the games. The purposes of this study were to help teachers to choose the right teaching strategy and offer appropriate analysis and suggestions for improvement through the integration of simulation learning into the instructional design of information and communication security and investigate whether there are differences in their learning effectiveness.

2. LITERATURE REVIEW
2.1. Current Situation of Information and Communication Security Education
For the education and instruction of information and communication security, scholars care about the problem that learners’ information technique is inadequate; for field experts, they focus on the problem that it is not easy to compile teaching materials. Because the difficulty of the material is not consistent, it tends to produce learning disability for learners and they
lack testing environment of doing information and communication security research. Scholars and experts consider that the most emergent focuses are to build up concepts about information and communication security and deliver them correctly [6, 8, 10, 15, 20]. Table 1 shows the summary of related data.

Table 1. For the current education and instruction of information and communication security, what are the obstacles and problems? (summarized by this study), referring to [6, 8, 10, 15, 20]

<table>
<thead>
<tr>
<th>Obstacles and Problems</th>
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<tbody>
<tr>
<td>Building up concepts of information and communication security and delivering them</td>
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<tr>
<td>correctly and broadly are not easy.</td>
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<td>Information and communication security education should include all-faceted</td>
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<tr>
<td>implementation.</td>
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<tr>
<td>For education of information and communication security, because training resources</td>
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<tr>
<td>are limited, sometimes it may cause problems of the quantity and quality of the course</td>
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<tr>
<td>and hence form a vicious circle. People who really need training and education may</td>
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<tr>
<td>not obtain the best quality of the course, and hence the advancement of professional</td>
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<tr>
<td>skills will be limited.</td>
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<tr>
<td>Due to the broad width of the field of information and communication security, it is</td>
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<tr>
<td>not easy to compile the teaching materials. The difficulty of teaching materials is</td>
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<tr>
<td>not consistent, and learners’ backgrounds are different, therefore these may cause</td>
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<td>learners’ learning disability.</td>
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<tr>
<td>Information technology related to information and communication security is not</td>
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<tr>
<td>sufficient.</td>
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<tr>
<td>It lacks the testing environment of doing information and communication security</td>
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<tr>
<td>research.</td>
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<tr>
<td>The field of information and communication security is too broad, and the importance</td>
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<td>of the combination with actual cases should be emphasized.</td>
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<td>Information and communication security education and development should be valued</td>
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<tr>
<td>more for the curriculum of all departments of information and communication security</td>
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<td>(system, program, maintenance).</td>
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</table>

Based on Table 1, this study also conducted an analysis and found out several core problems with the most influence on information and communication security education: because training resources are limited, sometimes it may lead to that most learning cannot be done under real situation; it is not easy to compile information and communication security teaching materials; the difficulty of teaching materials is not consistent, learners’ backgrounds are different, and therefore these may cause learners’ learning disability.

To solve the above-mentioned problems, based on related literature, this study brought up the idea to construct a diversified, adaptive and interactive learning material of information and communication security by the method of digital game-based learning expecting to reduce learner’s learning threshold and disability and improve their learning quality and effectiveness. The largest difference between traditional teaching materials and digital teaching materials
lies in the change of learning method; traditional ones always center on teachers and they deliver the uniform contents to different students during the class. Digital teaching materials center on students and apply digital technology to link teachers’ digital teaching materials and deliver different contents to different students according to their levels and needs [24]. Through the complete structure, sequence and experience, along with behavioral objective and prerequisite, instructional event, instructional process, instructional delivering method, choosing instructional media and instructional evaluation [5], the teaching materials satisfying learners’ learning needs can be designed. Different from traditional ones structured by linear way, digital ones can exert the advantages of multi-faceted integration; researches showed that using digital learning method have a higher learning effectiveness in academic performance and self-efficacy than using traditional one [2]. Digital teaching materials can cooperate with a variety of instructional objectives, and it is easy to do planning and management. For instance:

Game-based learning reflects and produces a virtual environment [1, 3, 14] through the medium such as character, sound, image, and animation, and it provides learners with an experiential and participative learning environment. The integration of game into information and communication security course allows learners to fully stimulate and develop all kinds of ability, to grope and practice repeatedly through playing games, and to grasp skills they want to learn and intricate concepts and knowledge through the formative evaluation in games.

Most teaching materials of information and communication security are conceptualized, and so it is always hard for learners to cognize and understand the principles and it deepens the difficulty of the design and production of them. Learning objective is a significant guidance to the design of teaching materials; curriculum analysis and design are the cause, and learning objective is the result. In J. S. Bruner’s learning theory, he emphasized using enactive representation, iconic representation, and symbolic representation to reinforce the cognitive development [10].

A good teaching material design has to do analysis about learners’ need, background, knowledge and skill base first, and then to plan appropriate learning objective according to their abilities. After the learning objective is confirmed, then suitable pedagogy and activity can be put into it. As a whole, all systematic teaching models are closely tight with these three elements – instruction objective, instruction strategy, and evaluation. Integrating self-learning design into information and communication security teaching material is able to arouse learners’ interest, offer suggestions for learning skills, improve their passive reading habit, encourage them to participate learning activity, and finally achieve instructional objectives.

3. RESEARCH DESIGN AND METHODOLOGY
This study aimed to understand the influence of applying game-based learning material in
information and communication security curriculum on learning effectiveness. For the teaching material design of theory and practice of internet security, the design of this study emphasized the following points: 1. The combination of simulation learning with the interactive mechanism of digital game-based learning helped learners to do reflection and strengthen the memory. 2. The subjects of this study were learners outside of normal distribution, that is, on-the-job students of evening or weekend program for working professionals, therefore they were so distinct and this study provided an adaptive simulation learning and game model to enable them to advance the problem-solving ability and mathematical calculation skill. 3. It was expected to improve learners’ feedback and allow them to have in-depth internalization and construct their own knowledge.

Learners in the game were able to use the learning process in the teaching material to assist them to learn. This study established two game-based teaching materials with a complete story. Players played the leading roles in the game, and the major focus was learners’ individual learning experience and the process of problem solving. In the game, there was a tracing function with the digital game-based learning material in each barrier.

3.1. Practice Curriculum Design
The subjects were the students of on-the-job graduate school not major in information engineering and information and communication security. This study created an “Internet Security Theory and Practice” course [25], and the focus was Public-Key Cryptosystems – using Chinese Remainder Theorem (CRT) to speed up RSA decryption.

3.2. Instruction Objectives
Knowledge: To be able to understand clearly the basic concept and related theories of using CRT to speed up RSA encryption and decryption
Skill: To train learners to be able to use CRT to speed up RSA encryption and decryption
Affection (Attitude): To be able to analyze and study CRT and apply CRT to speed up RSA encryption and decryption

3.3. Teaching Material and Activity Design in the Course
Teaching material and activity design should be closely related and connected to learning objective; it takes different instructional activity to achieve various kinds of learning objective, and therefore instructional activity should be based on learning objective to ensure that learning is not distracted.

Stimulate learning motivation: explain CRT and its calculation process by animation

This study added a problem-solving teaching assistant to help learners to learn basic knowledge, to explain them clearly, and to lead learners who didn’t understand the principle of encryption and decryption. For instance, “Light Intelligence Agent” is a role to assist
learners to learn the concepts of using speed up RSA encryption and decryption as Figure 1 shows.

This study produced a simulation and interactive game that learners have to solve problems independently, and led them to learn step by step during the problem-solving challenge with the interactive and interesting animation different from ordinary ones.

![Figure 1. “Light Intelligence Agent” animation in the teaching material of game-based learning](image)

### 3.4. Simulation and Interaction

The subjects of this study were the students of one on-the-job graduate school, and their average age was higher than that of full-time ones. Therefore, for the planning and design of instructional method and media, their learning habits need to be suited. Simulation and interaction were presented by multi-line interactive script (Figure 2) and the storyboard: “Make-Up Exam” was another game of role play to learn the concept of CRT (Figure 3), and it precisely connected the whole lesson plan. According to learners’ needs, this study designed a menu interface easy to use and offered related information.
Figure 2. Learning scenario design in digital gamed-based learning – some animation storyboards, CRT-Game as an example

Storyboard design of the teaching material of digital game-based learning on information and communication security: take some CRT storyboards as examples, as Figure 3 shows.

Figure 3. CRT – Some storyboard designs of “Make-Up Exam”

4. DATA COLLECTION

Within recent years, qualitative research is regarded by most to be able to do the in-depth investigation of complicated problem on a small number of subjects [16]. The focus of this type of research is the subject, and further is to understand their reaction, behavior, attitude and phenomena [19]. In-depth interview is one representative method of qualitative research. This study selected 5 students whose original grades were the 2-quantile and 3-quantile as the interviewees and conducted observation and in-depth interview. In conducting content analysis, the researcher had to read and analyze interview records repeatedly and then compare them with the researcher’s thought, viewpoint, and collected literature and data [12].

The following describes the data collection process of this study: this study collected literature related to the bottleneck and difficulty in the aspect of teaching and education of information and communication security and opinions from scholars and experts, and then did analysis and determined interview outline and interview subjects. After the subjects had learned the digital game-based information and communication security teaching materials, the researcher started to do the official interview and recording. After the interviews were over, the researcher typed the content of interviews into word-for-word script and did analysis and generalization, and finally compiled this study.

4.1. Subjects
The teaching material of simulation learning on information and communication security of this study was provided for 19 graduate students of on-the-job graduate school in the course of theory and practice of internet security in the second semester in 2008 to learn for 2 months.

Research tools in this study included the researcher, interview outline, recording machine, and interview recording table. The researcher interviewed the subjects according to the interview outline, recorded them and typed the interview records. This study was the observations and in-depth interviews on 5 subjects expecting to have an in-depth understanding about the theme of this study through the interviews and offer more opinions and suggestions for problem solving and improvement. This study utilized in-depth interview, and the official interview site was in the meeting room on the 1st floor of graduate institute of information and computer education in National Kaohsiung Normal University. The researcher asked the questions according to the interview outline and interviewees expressed their true thoughts about their feelings, understanding, experience, and realization. During the interview, when interviewees had doubts, the researcher would explain and clarify things regarding to their feedbacks.

4.2. Data Presentation and Content Analysis
After the interviews were over, the contents should be typed word for word and key points would be discovered during the analysis process. Therefore, the coding of the document had to be explicit. There were 2 interviewees, hence the sequence of the code is: the code of interviewee, page number, and line number. For instance, for the record of the 5th line on page 1 of interviewee A was represented as (A:1:05), and for the record of the 3rd to 8th line on page 2 of interviewee B was represented as (B:2:03-08).

5. DATA ANALYSIS
5.1. Data Analysis Method
For the in-depth interview of this study, it was done according to Tayor and Bogdan’s definition [11], the principle of the design and implementation of qualitative interview, and then the data was registered and sorted according to the [24] dominant and recessive registration principle related to content analysis. During the interview, the researcher would clarify regarding to interviewees’ feedbacks.

5.2. Interviewees’ Personal Data
For the selection of interview subjects, this study chose 5 subjects whose original grades were the 1-quantile and the 3-quantile to conduct in-depth interviews. Their personal data showed in Table 2.

Table 2. Personal Data of 5 Interviewees
<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Gender</th>
<th>Current job</th>
<th>How many years are there since the last education was finished till now?</th>
<th>Current education level</th>
<th>Interview site</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Male</td>
<td>An engineer of certain hospital</td>
<td>16 years</td>
<td>Master</td>
<td>1st interview: the meeting room on the 1st floor of graduate institute of information and computer education in National Kaohsiung Normal University (NKNU) 2nd interview: the restaurant near NKNU</td>
</tr>
<tr>
<td>B</td>
<td>Male</td>
<td>An engineer of certain telecommunication company</td>
<td>9 years</td>
<td>Master</td>
<td>1st interview: the meeting room on the 1st floor of graduate institute of information and computer education in NKNU 2nd interview: information classroom on the 3rd floor of graduate institute of information and computer education</td>
</tr>
<tr>
<td>C</td>
<td>Female</td>
<td>An employee of Kaohsiung Information Education Center</td>
<td>6 years</td>
<td>Master</td>
<td>the meeting room on the 1st floor of graduate institute of information and computer education in NKNU</td>
</tr>
<tr>
<td>D</td>
<td>Male</td>
<td>A teacher of Kaohsiung Information Education Center</td>
<td>14 years</td>
<td>Master</td>
<td>the meeting room on the 1st floor of graduate institute of information and computer education in NKNU</td>
</tr>
<tr>
<td>E</td>
<td>Male</td>
<td>An information engineer of certain company</td>
<td>9 years</td>
<td>Master</td>
<td>the meeting room on the 1st floor of graduate institute of information and computer education in NKNU</td>
</tr>
</tbody>
</table>
5.3. Content of Interview

This study extracted parts of the interviews of two representative subjects, the summary is as follows:

Topic 6. Do you think there are learning disabilities when you take the course of information and communication security? Please list these learning disabilities. Why do you have them?

These two interviewees had the same problem and confusion about learning knowledge and the understanding of information and communication security course.

“Take the course of information and communication security for example; actually it includes lots of concepts about security and attack/defense, and many theories. There are so many theories, so for us, we have to learn so much; in fact, it is not so easy. I may need to repeat learning them many times, and this is my disability. For instance, I want to understand an algorithm, and if I do not know where it comes from, then I may not know why it should be so. (A : 2 : 02-05)

“I am not good at mathematics, and when I have mathematic questions to solve, I will be very frustrated.” (B : 1 : 21)

Topic 14. When you use the digital game-based teaching materials to learn the course of information and communication security, how do you feel? Why?

I think it took so much time to learn it, and it indeed attracted me, so I am willing to offer some suggestions to make it better. (A : 3 : 12-13)

The evolution of the equation in the animation of the film really impressed me. I think the game in this material already turned an equation into images and films. Currently, people are talking about memory learning, which means to memorize by images. For some complicated equations, this method will impress people more… (B : 2 : 25-27)

Topic 16. When you use the digital game-based teaching materials to learn the course of information and communication security, what things do you find interesting? Why?

When these two interviewees were asked this question, they were very sure that the materials attracted them and they found them very interesting and thought they were helpful to learning.

“The animation made me feel interesting, and the idea and the way of presentation also made me feel very interesting.” (A : 3 : 20)

“Games with stories and also the presentation of the teacher can interest people. In the past, when I read textbooks edited by National Institute for Compilation and Translation, I think they…were very stiff, and I found out that textbooks edited by other publishers were very rich in information which always had some interesting stories and annotations on them. When I read textbooks edited by National Institute for Compilation and Translation and felt tired, I would read those edited by other publishers and found them interesting and I could carry on
reading them…Your materials have this kind of effect.” (B : 3 : 10-14)

Topic 18. Are you willing to keep on using “Digital gamed-based teaching materials of information and communication security” to do learning? Why?
These two interviewees said they are willing to keep on using the materials. Particularly, B mentioned that this “Digital gamed-based information and communication security teaching materials” helped him to do memory linkage, and with virtual scenario, it could provide a good condition for learning.
“Yes. It will be better if there are more digital teaching materials for us to learn like this one…” (A : 3 : 27)
“Yes. I have already mentioned the reasons. Besides, I want to know what I did not understand beforehand, and I want to understand them once I watch or read them. For taking notes, I will forget them after a long time. Then, through reviewing them by this (Digital gamed-based information and communication security teaching materials), sometimes it will prepare you to learn soon…” (B : 3 : 22-25)

6. RESEARCH FINDINGS
Through the above-mentioned observations, collection, analysis, generalization, summary of collected data, and literature review, it was found out that there were indeed several distinct merits in using digital game-based information and communication security teaching materials to learn this subject. For instance, in topic 14 when they were asked the question, both of them regarded this learning method was a very good way and it did stimulate learners’ learning interest, guide them to cognize the concepts, and strengthen the comprehension. In topic 18, they were asked are they willing to do learning by “digital game-based information and communication security teaching materials”, and one interviewee considered that this way of learning was helpful to do memory linkage, and coupled with virtual scenario, it could prepare him to learn soon. It did achieve the effects of self learning and promote the self-efficacy.

From the observations, the researcher also discovered that many learners who did not understand the algorithm or concepts had more learning disabilities than normal ones did. As far as the information and communication security and communication teaching materials in this study are concerned, one algorithm process of encryption and decryption would apply lots of different algorithmic concepts and methods, and learners would probably get stuck in these concepts and they could not precisely point out their problems. Even though they ask others who know how to do it, they may not understand each other’s words; the reason is that learners who know it cannot understand the key obstacles of the understanding of those who do not understand. In addition, one algorithm always includes many formulas, and sometimes those who understand them will tend to neglect or simplify some operations unconsciously; however, for those who do not have the concepts of mathematic operation at all or do not
understand them completely, these points may be what they do not grasp. Therefore, according to the interview results of this study, most interviewees considered that the digital game-based learning materials of information and communication security in this study not only got rid of the past image of traditional stiff, boring and dull textbooks of information and communication security but also strengthened learners’ construction of knowledge and internalization and stimulate and deepen the memory linkage during the learning process by using the equation instruction of images and animations in the materials. Besides, the simulated calculation process fully actualized the learning objectives of this material and advance learners’ comprehension and cognitive ability.

7. LIMITATION AND SUGGESTION

7.1. Limitation
The major limitation of this study is that it takes a very long time to produce one set of digital teaching materials; just analyzing learners, integrating content experts’ opinions, and designing instruction and teaching material will take a long time (maybe several years). In addition, producing one set of interactive game-based teaching materials also takes time and energy. Due to the limit of time, there is still incompleteness and room for improvement.

7.2. Suggestion
As for the course of this study, there are a variety of operations, such as division algorithm; learners of different stage (age) learn different methods. Once they encounter the operations different from theirs, they may have resistance because they are unfamiliar with them. As a result, different operations can be added and annotated in the material in the future. The researcher expected to give learners more diversified learning methods.

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