Design Principles of Instructional Materials for Cultivating Attitude and Ability to Utilize ICT while Considering Ethical Issues and Safety

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Abstract

Recently, performance standards have been defined in many subject areas in order to maintain the quality of school education. However, the quality of Japanese education is largely managed by controlling its contents through checking and authorizing textbooks based on national curriculum guidelines. In Japan, when teachers focus on educational content, they often expect students to memorize information, and when they focus on performance, they believe it is sufficient to achieve the objectives of the lesson as long as activities that simulate the context of daily life are occasionally offered. We believe that this existing quality management system should be changed to reflect that the objectives of education have shifted from providing knowledge to developing intellectual skills. Accordingly, teachers should consider the model of cognitive process as well as the relationship between this process and knowledge, rules, procedures, values, ethical codes, etc., that students are expected to learn. In this paper, we describe the development of a new e-learning material for Information Studies based on improved design principles derived from our previous studies. Our new e-learning material, "Security Policy" game, asks students to construct security policies for using a computer classroom in a school. In addition to analyzing the findings from experimental lessons, we describe a plan for teacher training that utilizes the game.

Approach to Informatics Education and Cyber Ethics Education

The necessity of informatics education has been highlighted in many countries. For example, the Programme for International Student Assessment (PISA) assesses students' ability to utilize information and communication technology (ICT) in problem solving (OECD 2009), and the Partnership for 21st Century Skills (2009), in participation with the US Department of Education, promotes information, media, and technology skills that students should master in order to succeed in work and life in the 21st century. Though media literacy educators consider informatics education

as an extension of the 3Rs, with a focus on the objective of understanding information critically, we believe it should be implemented as a part of technology education. This is because informatics became necessary through the advancement of ICT, and therefore, students should learn how ICT works in order to fully understand its features.

To solve a problem using ICT, one must consider the quality of both the results and the method/process. The latter includes consideration of the ease, cost, safety, and efficiency of the process, which is important in any lesson on cyber safety and ethics. Though similar forms of education are often referred to as "information ethics" (Floridi 1999) or "digital citizenship" (Ribble & Bailey 2007), in Japan, it is known as information moral education (MEXT 1999).

Many types of instructional materials and teacher guidebooks are available for cyber ethics education. However, Hirabayashi et al. (2011) pointed out that most of them focus on negative instructions for students to memorize, such as "Do not..." and "It is dangerous because ...." Einaga and Matsuda (2007) further noted the following three issues regarding the current method of cyber ethics education in Japan: (1) The time allotted to lessons that focus on cyber ethics education is rather limited. (2) The instructional method that instills knowledge using case-based rules does not stimulate ways of thinking about questions such as "Why shouldn't one do....?" Therefore, it does not cultivate the ability to keep up with advances in technology. (3) The current method tends to foster a negative attitude toward ICT.

In order to solve the problems posed by (1) and (2), Tamada and Matsuda (2004) proposed an instructional method aimed at teaching cyber ethics judgment on the basis of a combination of the following three types of knowledge: "ethical code knowledge," "knowledge of ICT," and "knowledge of rational judgment." Then, in order to resolve the problem of (3), Hirabayashi et al. (2011) and Hirabayashi and Matsuda (2011) described an instructional method that integrates 13 items of "informatic and systematic thinking," which Matsuda (2003) proposed for effective use of ICT, with the three types of knowledge listed above. They developed e-learning materials based on this method and verified the positive effects of the materials on students' learning.

Hirabayashi et al. (2011) further pointed out that instructional methods for cyber ethics education in foreign countries also tend to focus on negative instructions. Therefore, their method may be applied toward improving cyber ethics education in other countries as well.

From Instructional Materials Design to Lesson Design

Recently, performance standards have been defined in many subject areas in order to maintain the quality of education. However, in Japan, quality of education is controlled by using national curriculum guidelines, set by the government, to check and authorize textbooks. Thus, quality of education is managed largely through lesson contents, except in subject areas where teachers emphasize practical works and seldom use textbooks. This system of quality management reflects an educational culture in which Japanese teachers tend to teach knowledge; they expect students to memorize important information when the class is focused on content. On the other hand, teachers in practical subject areas tend to consider that it is sufficient to achieve the lesson's objectives as long as activities that simulate the context of daily life are occasionally offered.

In this school culture, informatics education is conducted mainly in compulsory subject areas —"Information Studies" in upper secondary schools and "Industrial Arts and Home Economics" in lower secondary schools. Information Studies teachers emphasize either activities such as computer/software operation, multimedia design, and giving presentations and holding discussions after online research, or those such as memorizing the latest technical knowledge and judgment rules for cyber safety and ethics. This practice has led the Central Council of Education (2008) to point out that the existing instructional method of informatics education in Japan does not cultivate students' problem-solving abilities.

We believe that the national curriculum guidelines and approved textbooks are not enough to manage the quality of school education in Japan. Although the objectives of education have shifted from providing knowledge to developing intellectual skills, teachers lack the pedagogical training

necessary to effectively reach this goal. They should strive to base their teaching approaches on consideration of the model of cognitive process as well as the relationship between this process and knowledge, rules, procedures, values, ethical codes, etc., that students are expected to learn.

According to Ishii and Matsuda (2003), teachers must realize three main goals to utilize ICT in lessons or to teach informatics: They should (1) recognize the necessity of developing students' problem-solving abilities, (2) understand features of appropriate lessons that foster problem-solving abilities, and (3) redesign their lesson plans accordingly. We consider that our instructional materials can be used in teacher education courses to achieve goals (2) and (3).

Purpose

In this paper, we describe the development of a new e-learning material for Information Studies based on improved design principles derived from our previous studies. The new e-learning material, "Security Policy," asks students to create security policies for using a computer classroom in a school. In addition, we describe a teacher training method that utilizes this e-learning material, based on findings from an experimental lesson.

Design Principles of Gaming Materials for Information Studies

According to the revised national curriculum guidelines of Japan, as of 2013, students must elect to study one of the following two subjects: "Information Studies for the Global Community" or "Information Studies by Scientific Approach." Because the former is expected to be chosen by more than 80% of students based on the current selection ratios of similar subjects, we had developed instructional games corresponding to the first and the second of the four units in the former subject. In the first unit, students learn about digital technology and utilization of multi-media technology. Therefore, we selected the topic "Designing an Effective Presentation" for the game. In the second unit, because students learn about utilizing the communication network, we developed an "Internet Auction" game.

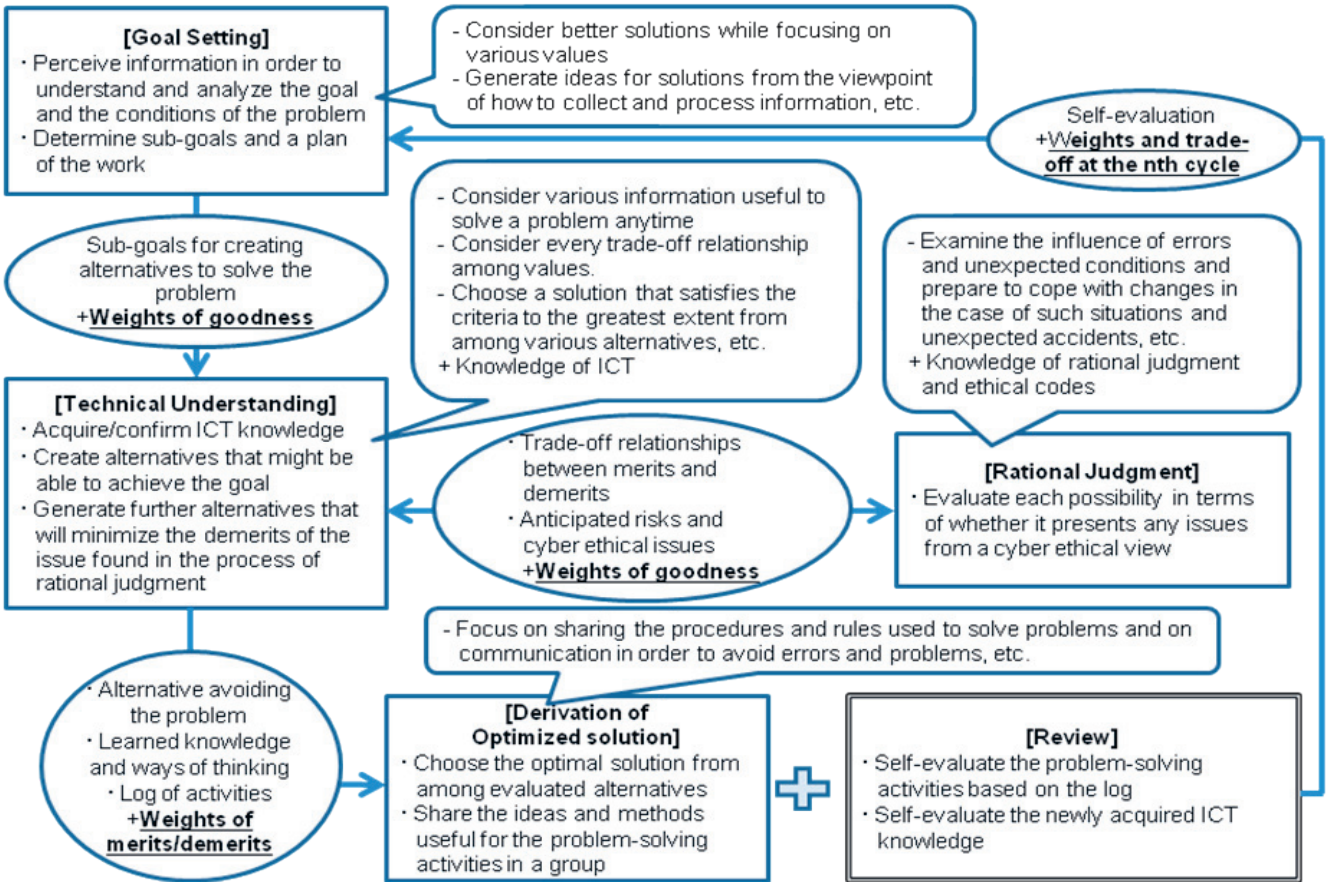

Figure 1 Design principle of the instructional game materials

When we developed the games, we constructed the design framework shown in Figure 1. First, we divided the problem-solving process into four sub-processes, shown in the rectangles: goal setting, technical understanding, rational judgment, and derivation of optimized solution. These categories are based on Savery's (2009) framework of Problem-Based Instruction. The design framework is intended to integrate informatic and systematic thinking with the three types of knowledge mentioned earlier and to clearly show students where each of them should be utilized in the task of problem solving, as shown in the balloons in Figure 1. All three types of knowledge are required for the "technical understanding" and "rational judgment" processes. In the technical understanding process, students generate several possible plans as they learn about ICT. In the rational judgment process, they evaluate each possibility in terms of whether it presents cyber ethics issues, considering knowledge of both ethical codes and rational judgment. If a plan is found to present any issues, the students may disregard it in favor of another plan or return to the process of generating ideas. Each oval in Figure 1 lists the elements that should be determined in each process in order to be used in the next.

Because the game is intended to be used at the end of each lesson unit, it requires students to go through all the sub-processes of problem solving. In addition, as an instructional game, rather than a test, the materials should offer students the opportunity to try again. Therefore, we added a "Review" stage, represented by the double-lined rectangle in Figure 1, as well as referring the manner of gaming simulation: briefing -> game play -> debriefing (Matsuda 2011). This feature of the game design renders the whole process into a cycle, allowing students to solve similar but different problems under various conditions. It also introduces the challenge of flexibly applying their skills to changing circumstances.

From the results of trial lessons conducted with 51 students at a women's university, we confirmed that, after playing "Designing an Effective Presentation," students better recognized the

importance of utilizing informatic and systematic thinking in problem solving. For example, they were significantly more likely to agree with the statement "We should study a thinking method for how to apply our ICT knowledge when assessing cyber ethics problems" and significantly less likely to agree that "When problem solving, we should resolve the problem using customary methods." However, regarding agreement with the statement "Considering trade-offs prevents us from solving problems," we found a difference between the responses of those who indicated alternatives to improving the problem in addition to pointing out cyber ethics issues (26 students) and the responses of those who did not (20 students).

This tendency was revealed in the log analysis. However, evaluation in the game must provide immediate feedback on whether students have demonstrated sufficient knowledge of ICT and whether they have utilized informatic and systematic thinking; therefore, we needed to revise Figure 1 to reflect the results of the trial lessons as underlined elements of each oval. Moreover, though we originally created the elements according to the topic, we should add more, such as the merits/demerits that are considered in the problem-solving process as well as their weights and trade-off relations when students evaluate the various possible plans. These elements should examine whether the weights are consistent with the students' evaluation of each idea.

Furthermore, in the review process, although it is important to evaluate the wisdom of students' decisions, it is more important to assess how the students utilize informatic and systematic thinking and the range of merits/demerits they take into consideration. In order to evaluate these points reliably in the game and make students conscious of their own learning, we prepared a common framework of evaluation. That is, we improved Matsuda's (2011) rubric for evaluating student competency to utilize several views and ways of thinking. If discrepancies are found between a student's self-evaluation and the activity recorded in the game, students are asked the reasons for their self-evaluation when they receive feedback about the discrepancy. Moreover, they are asked to explain their newly acquired knowledge of ICT.

Development of New Gaming Material: "Security Policy"

"Security Policy" is the main topic of the third unit of "Information Studies for the Global Community." In this unit, students learn about personal authentication, encryption, rules, and laws related to information security, etc., through examples of familiar situations. Moreover, the unit objectives are not only to acquire knowledge but also to learn methods of building group consensus concerning rules and policies.

"Security Policy" was developed under the same constraints as our previous materials: (1) Students must finish the game in an hour, which includes the time taken by teachers to explain the instructions, and (2) students are asked to accomplish a certain mission by weighing trade-offs between achieving a higher goal and avoiding various problems. Moreover, in order to cultivate the students' competency in making appropriate decisions according to the situation, the game enables them to play multiple times under changing goals and conditions.

In the goal-setting process, a student defines his/her goals for creating an adequate security policy after the teacher describes the current state of information security. A tablet terminal with a wireless LAN connection is assumed to be available to each student in the game. The student is asked to identify the various merits/demerits of the present security system and to list issues to be resolved. He/she is also asked to distinguish constraints from goals according to the analysis of information that he/she will collect individually and to form a plan for creating an adequate security policy that everyone can agree on. When the student evaluate all the potential plans at a later stage, the weights of goodness will be estimated based on his/her goals.

In the technical understanding process, the student is asked to brainstorm alternative ways to manage the computer room more securely, to evaluate each alternative considering trade-off relationships between its merits and demerits, and to estimate the influence of potential security incidents as well as the probability of their occurrence. The goal of this process is to encourage the student to define criteria for choosing the optimal solution from among a set of alternatives. The

weights of goodness change according to the number of generated alternatives, their effectiveness/usability/risk, the student's trade-off judgments, and the evaluated severity of incident.

In the rational judgment process, the student considers the issues of the leading alternative using ICT knowledge and rational judgment: "Has the law been broken?" "Are others injured?" "Could I injure myself?" If any problems are found, the student returns to the technical understanding process to generate further alternatives that will minimize the demerits of the issue. The weights of merits/demerits change according to where the issue is found and the features of the improved alternative.

In the derivation of the optimized solution process, each student creates a security policy by choosing the optimal solution from among the alternatives generated and evaluated in the previous processes. Then, he/she moves on to the review process to evaluate both the security policy he/she has adopted and the weight of each merit/demerit evaluated through the previous processes. According to this information, the student checks whether these weights are consistent with the goal. Moreover, each student evaluates his/her own problem solving based on the rubric. If any discrepancies are detected between the self-evaluation and the activity recorded in the game, these are drawn to the student's attention through appropriate feedback. After the self-evaluation, the teacher in the game prompts the students to problem solve in a different situation by stating, "Since the situation has changed, I want you to re-consider the security policy you created."

Experiment and Discussion: Application to Teacher Education

We conducted experimental lessons with 171 students at an upper secondary school. We verified the effectiveness of the lessons according to the log data and a pre- and post-questionnaire. Significant differences in the responses on the pre- and post-questionnaire indicated the game was effective at providing students with confidence to utilize their ICT knowledge as well as informatic and systematic thinking in problem solving. In addition, the students recognized the importance of creating ideas to minimize demerits and avoid anticipated problems. However, we also found that students who lacked confidence tended to generate few and inadequate ideas that were inconsistent with their goals. Therefore, teachers should teach ICT knowledge well before implementing the e-learning games so that students are properly equipped to utilize this knowledge in their problem solving when they play.

Based on this study and our previous ones, we plan to develop a "virtual lesson" game to promote teachers' professional development regarding how to give effective lessons on Information Studies. As Ishii and Matsuda (2003) suggested, firstly, we must prompt teachers to recognize the necessity of promoting students' utilization of informatic and systematic thinking as well as the importance of integrating informatics education and cyber safety/ethics education. Secondly, we should encourage teachers to play "Security Policy" as students; this will fully familiarize them with all aspects of the game and provide them with insights into the student perspective. Finally, we should ask teachers play a "virtual lesson" game that simulates a lesson on "Designing an Effective Presentation" in order to evaluate the adequacy of their decisions and provide feedback to improve their lesson plans based on our design framework.

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