A CASE STUDY ON THE APPLICATION OF THE COMPUTATIONAL THINKING-BASED CREATIVE PROBLEM SOLVING (CT-CPS) INSTRUCTIONAL MODEL

Yongju Jeon, Seokjeon Kim, Seungchul Lee, Taeyoung Kim
Korea National University of Education (SOUTH KOREA)

Abstract

Today’s dramatic change of diverse activities and policies on computing education has its root in the prediction that talents equipped with creative computing competence will determine the competitiveness of a nation in the future. From this point of view, we developed the computational thinking-based creative problem solving (CT-CPS) instructional model in our previous study, on which students can develop their computational thinking ability in the context of the creative problem solving process. This study is a follow-up study on the real world application of our instructional model. In this study, we first conducted a lesson plan based on the CT-CPS instructional model and then applied it to elementary informatics gifted students. After the experiment, we compared creative problem solving ability through pre-post test comparison and drew implications for possibilities of our instructional model.

Keywords: Computing Education, Computational Thinking, Creative Problem Solving.

1 INTRODUCTION

Today’s dramatic change of diverse activities and policies on computing education has its root in the prediction that talents equipped with creative computing competence will determine the competitiveness of a nation in the future. Following this timely trend, the issue of creative computing education came to the lime light recently receiving world wide attention. Not only the public or private educational institution, but also private companies and organizations are implementing diverse educational programs under the name of computing education [1–3]. In the United Kingdom, computing has been incorporated into the public education curriculum since 2013 [4]. Other countries also begin to take actions participating in this trend, and South Korea is no exception. Since the Ministry of Science, ICT and Future Planning of South Korea announced innovative strategy in 2013 for cultivating computing education as a tool for realizing creative economy, it is promoting diverse activities and policies along with the Ministry of Education of South Korea making efforts to include the information-related subject, i.e., computing into the 2018 curriculum revision [5-6].

Diverse studies on the new creative computing education are currently under progress both domestically and internationally. Wing (2006, 2008) asserted that computational thinking (CT) refers to a process of thinking and problem solving that uses computing techniques such as abstraction and automation [7-8]. Many researchers argue that this is the new methodology of integrative problem solving through computing, and they are currently conducting studies that can apply the methodology to diverse curricula [7-12].

Based on these related points of view, we developed the computational thinking-based creative problem solving (CT-CPS) instructional model in our previous study, on which students can develop their computational thinking ability in the context of the creative problem solving process. This study is a follow-up study on the real world application of our instructional model. In this study, we first conducted a lesson plan based on the CT-CPS instructional model and then applied it to elementary informatics gifted students. After the experiment, we compared creative problem solving ability through pre-post test comparison and drew implications for possibilities of our instructional model.

2 THE STUDY

2.1 Computing education for cultivating creative and integrative talent

Dijkstra (1971) once pointed out the problem of programming class in computing education comparing it to the situation where taking driving class before obtaining driver’s license is useless for gaining
actual driving skills [13]. In other words, traditional computing class was mainly an education about programming that had little applicability to the actual problems of the world. Taking a lesson from this viewpoint, it will be necessary to develop a new computing education contents that can be useful for solving actual problems, and further, the new computing education should be able to cultivate students’ creative and integrative talent.

CSTA Standard Task Force (2011) identified five strands of computer science education. It is noteworthy that CT and computing practice are different strands [11]. CT encompasses problem-solving methodology with algorithmic procedures and computing, and computing practice refers to the technical aspects associated with the actual programming practice (See Fig. 1). The standard makes it clear that, contents that form basis of creative and integrative thinking must be included in future computing education.

![Fig. 1 5-strands and 3-levels of the computer science education (CSTA, 2011)](image)

The National Curriculum in England(2013) asserted that a high-quality computing education equips students to use computational thinking and creativity to understand and change the world. And computing also ensures that students become digitally literate – able to use, and express themselves and develop their ideas through, information and communication technology – at a level suitable for the future workplace and as active participants in a digital world [4]. From these points of view, we redefined the characteristics of computing education as follows:

“An education for cultivating creative and integrative talent that can solve problematic situation in real life by actual computing practice and utilization of programming tool based on the understanding about the computer science and related thinking process.” [14]

2.2 CT-CPS instructional model

CT-CPS(Computational Thinking-based Creative Problem Solving) instructional model is a framework for the computational thinking-based education that can enhance creative competence, which is required in the current computing class [15]. CT-CPS instructional model incorporates the computational thinking ability (Wing 2006, 2008; Guo 2011; Barr et al. 2011) into the creative problem solving process (Osborn 1963; Parnes et al. 1967, 1977; Isaksen & Treffinger 1985).

Firstly, the class in the CT-CPS instructional model begins with problem recognition. During this process, the CT’s learning elements of data collection, data analysis, and data representation are used. Secondly, in idea thinking phase, students think about diverse ideas that can solve the problem at issue by making use of the relevant computing methods through a series of brainstorming, mind map, drawing and so on. The ideas are further simplified and abstracted so that it can be solvable at the learner’s level. Thirdly, in designing phase, solution ideas that were extracted in a simplified form are structuralized. In this stage, the flow chart and storyboard designing take place through the process of visual design and logical design at the learner’s level. Finally, in implementation and evaluation phase, designed solution is actually implemented using programming language through the process of draft writing (individual) and debugging (along with a teacher and peer). Afterward, the students present and demonstrate their completed output and manufacturing process, followed by feedback exchange of teacher observation and peer evaluation (See Table 1).
Table 1. The CT-CPS instructional model for computing education [15]

<table>
<thead>
<tr>
<th>Stages</th>
<th>Teaching and learning activities and learning medium(*)</th>
</tr>
</thead>
</table>
| Stage 1. Problem identification and analysis | • Motivation and introduction of tools used in the class  
  • Problem identification  
  - Data collection on the subject to be problematized (interview, survey, field investigation, etc.)  
  - Analysis and classification of collected data to be visualized (*tables, graphs, figures, etc.)  
  • Problematization  
  - Reason to solve this problem (purpose), knowledge relevant to the problem, the value of the problem  
  - Expression of a problem that should be ultimately solved (*writing, presentation, etc.) |
| Stage 2. Idea thinking | • Coming up with diverse ideas to solve the problem using computing  
  - Brainstorming, mind map, drawing, etc.  
  • Simplification of solution idea  
  - Solvable level, abstraction |
| Stage 3. Designing | • Design of the solution idea  
  - Sketching the initial solution by each scene (*paper, presentation, etc.)  
  • Making a logical flow chart  
  • Making a whole storyboard covering scenes and logics |
| Stage 4. Implementation and evaluation | • Implementation of the solution idea  
  - Making a implementation of the program based on a storyboard (* programming tools)  
  - Debugging (along with teacher and peer)  
  • Presentation and demonstration (*presentation tools, etc.)  
  • Evaluation and feedback exchange  
  - Teachers’ observation and peer valuation |

2.3 Scratch and App Inventor programming

Scratch and App Inventor, educational programming languages developed by the MIT Media Lab, are widely used in educational fields. The productions of the Scratch are animation and game programs based on the Adobe Flash player, and the results of the App Inventor are application package (apk) files executable on Android-based smartphones (See Fig. 2). Diverse instructional contents utilizing Scratch/App Inventor programming has been developed. Studies of the effects of Scratch and App Inventor have been conducted on learning flow and programming abilities, programming learning attitudes, self-directed learning abilities, learning motivation and academic achievements, logical thinking, and learning style and problem-solving ability and so on.
3 METHODOLOGY

In this study, we first conducted a lesson plan based on the CT-CPS instructional model and then applied it to elementary informatics gifted students. After the experiment, we compared creative problem solving ability through pre-post test comparison and drew implications for possibilities of instructional model.

3.1 Designing and application of the lesson plan based on CT-CPS instructional model

To design a CT-CPS instructional model-based lesson plan, we held a brainstorming meeting to selected open-ended subject for the computing education. As a result, we selected the subject named ‘Solving problems in surroundings by using App Inventor or Scratch’. The course subject was based on creative experience activity, life and information in the subject of practical arts, or contents that can be handled in everyday life or electrical and electronics field. The application procedure followed the four phases of the CT-CPS framework where each phase had a length of three to six sessions. Table 2 shows the lesson plan that was used in the field application.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Total teaching-learning activities</th>
<th>Homework (Instrumental learning)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Teaching-learning activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem recognition and analysis</td>
<td>1. Looking for the problem that the student wants to solve (observation, relevant data search, etc.)</td>
<td>Watching a basic level online lecture on App Inventor or Scratch (required)</td>
<td>Week 1 (Session 1–3)</td>
</tr>
<tr>
<td></td>
<td>2. Collection of data relevant to the detected problem (interview, Web searching, survey, field investigation, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Classification and visualization of the analyzed data (graph, table, chart, picture, texts, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Writing a inquiry report about the detected problem (on a given form)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idea thinking</td>
<td>1. Thinking about the problem solving strategy based on the inquiry report written in Week 1 (use diverse techniques such as brainstorming, mind map, and drawing)</td>
<td></td>
<td>Week 2 (Session 4–6)</td>
</tr>
<tr>
<td></td>
<td>2. Division of the ideas into two groups according to whether or not the student is capable of realizing them using their selected tools</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. The lesson plan in the field application
In Phase 1, the students wrote an inquiry report by setting up the problems by themselves and collecting relevant data to specify the problem. In Phase 2, the students were guided to think about the necessary ideas for actually solving the problem using programming tools and to estimate how much they can carry on by themselves. They were told to simplify the problem in case the problem is out of their scoop or too complicated to express. In Phase 3, for the purpose of fabricating the program for the given problematic situation, the students made the drafts of a flow chart, a design scheme, and a program coding. In Phase 4, the students finally debugged their own program together with a teacher and peers and demonstrated the summary of production procedure and their outputs to exchange feedback.

### 3.2 Experiments

In our six week course, students learn the basics of Scratch or App Inventor programming during the first three weeks. During this period, students simultaneously select a problem and analyze it based on the collected information and data. In the last three weeks, the design and implementation of a Scratch or App Inventor programming are carried out. It is a six week course and it took three sessions per week over the period of May 2015 through June 2015. 20 IT-gifted students in the fifth and sixth year of primary school took part in the experimental course. Table 3 shows the design of this study.

<table>
<thead>
<tr>
<th>Table 3. The design of this study</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
</tr>
</tbody>
</table>

G1 : Experimental group  
O1 : Pre test (Test of Creative Problem Solving Ability)  
X1 : CT-CPS based learning contents  
O2 : Post test (Test of Creative Problem Solving Ability)

And we used the simple creative problem solving test questionnaire, developed by Seoul National University MI Team (2004) and modified by Ku, J. (2016), as a research instrument [16]. The four sections suggested in this test are ‘Knowledge, Thinking skills, Understanding technique of a particular field’, ‘Divergent Thinking’, ‘Critical and Logical Thinking’ and ‘Motivation factors’. An assessment scale was a Likert-five level scale: “strongly agree”, “agree”, “neutral”, “disagree”, “strongly disagree” and the score was given from five to one point. The reliability of the test questionnaire was a Cronbach alpha of .907, which was very high. After the experiment, we compared creative problem solving ability through t-test comparison between pre and post test and drew implications for possibilities of our instructional model.
4 RESULTS

To achieve the goal of this study, comparison of mean difference between pre and post tests within a group was analyzed via two-dependent samples t-test ($p<.05$). The statistical software used in result analysis was IBM SPSS Statistics 21. Table 4 shows the results of the analysis.

<table>
<thead>
<tr>
<th>Sections</th>
<th>M</th>
<th>SD</th>
<th>$t$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge, Thinking skills, Understanding</td>
<td>3.98</td>
<td>.645</td>
<td>-2.236</td>
<td>.038*</td>
</tr>
<tr>
<td>Understanding technique of a particular field</td>
<td>4.08</td>
<td>.627</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Divergent Thinking</td>
<td>4.06</td>
<td>.702</td>
<td>-2.210</td>
<td>.040*</td>
</tr>
<tr>
<td>Critical and Logical Thinking</td>
<td>4.19</td>
<td>.589</td>
<td>-2.430</td>
<td>.025*</td>
</tr>
<tr>
<td>Motivation factors</td>
<td>4.13</td>
<td>.617</td>
<td>-2.990</td>
<td>.008**</td>
</tr>
<tr>
<td>Total</td>
<td>4.09</td>
<td>.547</td>
<td>-4.433</td>
<td>.000**</td>
</tr>
</tbody>
</table>

The pre-post test results within an experimental group about creative problem solving ability showed that all sections had significant improvements in the mean values. In particular, the $p$-value of the motivation factor section was .008 and the $p$-value of the critical and logical thinking was .025, which was a very low value. It indicates that self-directive lesson based on CT-CPS instructional model gave interests and motivation to the students and experiences about clarification of the problem and giving shape to a solution were helpful in improving critical and logical thinking ability.

The students continued writing a reflection diary during the education program period, and they revealed their feelings about the education by writing a note of impression after the presentation of the final output. Below are the excerpts from the students’ final impression note after deleting redundant comments and too general impression.

"I think I definitely grew up during the past few weeks. Rather than accumulating more knowledge, I feel that my point of view and problem-solving ability have changed. Moreover, building my own application was most memorable. I made "kinship degree calculator": During the process, I could feel the sense of accomplishment as well as learn new functions of a computer. It was a very exciting procedure."

"Last year, I participated in a creative talent experience group held by an educational university. There I conducted diverse experiments related to the scientific exploration. However, they were hard to follow in daily environment and as they required experiment tools, I was only aware of the principles without actually making use of what I learnt in real life. However, the gifted children class at this university taught us about how to actually solve the potential problem that can occur in the future. I felt comfortable learning relationship between a teacher and students, such as an atmosphere where anyone can raise their hands to cast a question, contributed to the better progress of the integrative project."

"Through this program, I learned about problem solving process, which I can make use of in my daily life. I think it can also be useful in my future job. Most of all, the program provoked my passion and interest (continued)"

"When I was studying, I analyzed questionnaire. But analyzing it was very difficult. Because it required a lot of time to examine more than a hundred questionnaires. I also had to make graphs and tables to use in the study (continued)"

Looking at the impression notes written from a viewpoint of the learners, they frequently said that they could develop their ability to express and use data, problem solving ability, and meta-cognitive ability through the CT-CPS class established in this study. Also, they commonly mentioned that they expect the CT-CPS instructional model to be applied in the actual school education.
And fig. 3 shows demonstration scenes of the production procedure of programs by students and their own output examples.

![Fig. 3 Outcomes of App Inventor and Scratch programming courses](image)

5 CONCLUSIONS

Even though the CT-CPS instructional model can be used as a class designing principle for the single session class, we think that in-depth investigation in each phase is also possible in the actual class. Hence, we recommend applying the framework to at least four sessions of class. Furthermore, the class construction process begins with problem recognition by students themselves. The CT-CPS instructional model in this study is in succession of the objective of problem or confusion detection pursued by the CPS technique. Here, emphasis is put on the process of independently detecting diverse problems related to daily life or relevant subjects and problematizing them. And learning about the programming software itself is done by subsidiary activities. That is, it is possible to implement the form of a blended-type class or flipped learning class where online lectures are uploaded on the Web site or the learning homepage to let the students learn about it by doing their homework.

The creative and integrative talent, which the Ministry of Education in Korea promised to foster in the summary of the new 2015 Integrative Curricula of Liberal Arts and Natural Sciences, refers to a person who is equipped with humanistic imagination, creativity in scientific technology, and upright character such that students is able to generate new knowledge and create new values by integrating diverse knowledge. Considering that those objectives are in line with the global trend, the current direction that the Korean education movement is aiming at seems very meaningful. Hence, in order to fully realize the objectives, SW education located at the core of the recent change should take correct direction and measures that requires integrative researches and efforts. We sincerely hope that this study can be used as a fundamental foundation for the future studies that explore methods for creative computing education in diverse fields.

REFERENCES


