International Journal of Internet, Broadcasting and Communication Vol.8 No.1 73-82 (2016)
http://dx.doi.org/10.7236/IJIBC.2016.8.1.73

IJIBC 16-1-10

A Practical Study on Data Analysis Framework for Teaching 3D Printing in Elementary School

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Abstract

The computational thinking refers to the ability to solve the complex and a variety of problems by utilizing a computer in core of the software education. It create a model through data collection and analysis and realize that the computer can understand to solve problems. Recently, the educational application of 3D printer appears in importance, which is one method to improve the computing thinking. In this paper, we propose the data analysis framework to stretch the computing thinking of learner that can incorporate 3D printing technology to the current elementary school curriculum and apply in a case study.

Keywords: *Data Analysis Framework, 3D Printing, Computational Thinking*

1. Introduction

The government of the Republic of Korea has recently fostered the industries related to 3D printing. Particularly, approximately 10 million students will have received education on applying 3D printing whilst schools will have been equipped with 3D printers by 2020 [1]. The rapidly spreading 3D printing technology[1] used to be functionally limited to the manufacturing field whereas it has recently been applied across the board[2]. In this context, the applicability of 3D printing technology to education[3] would shift the paradigm in school education. In the same vein, research on applying 3D printers to education has increased[4,5]. Yet, the environment for teaching 3D printing to elementary students has a long way to go, which is why it is urgent to develop some curriculums and textbooks relevant to 3D printers[1].

The essence of software education is the computational thinking[6,7]. The computational thinking refers to a computer-based problem solving by collecting and analyzing data and building up models of solutions for complex and diverse problems presented [8]. The application of 3D printers to education can be a means of increasing the computational thinking. Therefore, given the rising importance of software education, the educational applicability of 3D printers need be explored.

In this paper, we propose the data analysis framework for applying 3D printers to the current curriculum. The proposed data analysis framework is intended to design an instructional method based on software

Manuscript received: Jan. 12, 2016 / Revised: Jan. 25, 2016/ Accepted: Feb. 3, 2016
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engineering in order to induce the willingness to learn the 3D printing and to embed some programming features in the 3D printing. Also, in the proposed framework, the outputs of 3D printers can be gained through a 4-stage process, i.e. notice of themes and goals of learning, analysis and design, creation and execution, and evaluation.

This paper is organized as follows. Chapter 2 reviews the literature on the application of 3D printing technology and the computational thinking. Chapter 3 describes the data analysis framework designed to apply 3D printing to elementary schools. Chapter 4 elucidates the cases of applying the data analysis framework to analyze textbooks. Finally, chapter 5 presents the conclusion and future studies.

2. Related Works

2.1 3D printer application technology

Applying 3D printing technology to wind instrument outputs, Moon H.J.(2014) reported 3D lamination prototyping technology could adjust and improve musical instruments and enables people of every class to enjoy music [9].

Cho H.H. et al.(2014) applied the 3D printing technology to math instructions, and mentioned math learning activities using 3D printers could enable students to increase their computational thinking and to ponder upon and explore problems for the joy of achievement[10].

Han J.Y.(2013) applied 3D printers to analysis sheets and reported 3D printing technology was superior to the general manufacturing process in terms of manufacturing speed, product forms, surface finishing and diversity of materials [11].

Reviewing local and global trends in research on 3D printers, Kim M.J. et al. (2014) considered the local 3D printing design programs are very limited in comparison to overseas ones in general and especially in terms of teaching targets[12].

Up to now, research on application of 3D printing has mostly been relevant to industrial fields. From the perspective of educational applicability of 3D printing, learners can increase the computational thinking via the process of modeling outputs, which in turn can serve as diverse learning tools. Despite the foregoing educational value, research on 3D printing applied to education is far from sufficient. Thus, the present paper delves into the applicability of 3D printing in education.

2.2 Computational thinking

Recently, researchers in computer science assert that the computational thinking should be trained in order to increase the overall cognitive capability. Defining the process of thinking over solutions for problems as the computational thinking, Wing(2006) argued that everyone should learn and acquire the computational thinking[6].

Referring to the computational thinking as the expansion of human cognitive capability, Bundy(2007) asserted that the skill was part of the fundamental thinking skill for solving problems[13].

Wing(2008) clarified the difference between the computational thinking and the thinking skill dealt with in other disciplines, and characterized the abstraction in the computational thinking[1,7] as follows:

First, the abstraction in computing does not have the simplicity and clarity of mathematical abstraction but very general characteristics. Second, the abstraction in computing tends to be richer and more complex than that in mathematics or physics. The other core element of the computational thinking is automation. The abstract concepts generated through the abstraction process can be reinforced by the automation process using a range of computing devices, whilst the automation requires some devices that can analyze and implement the abstract concepts. Although the computer is the most generally applicable device, the performance of humans may be more meticulous and solid than that of computers depending on the attributes of abstract concepts [14]. That is, the computational thinking means solving problems using such capabilities as abstraction and automation.

For learners to raise their spontaneous computational thinking, they should be allowed to have greater autonomy in the process of learning the 3D printing and thus to define some abstract concepts as well as to implement them in reality.

3. Data analysis framework for teaching 3D printing

The proposed data analysis framework should induce the willingness of learners to learn the 3D printing. Also, it is necessary to design an instructional method to teach the 3D printing based on software engineering and to embed some programming characteristics in the 3D printing.

3.1 Principles of designing a instructional method

The present paper sets up the following principles of designing an instructional method fit for teaching and learning the 3D printing.

1) The functions of 3D printing tools should be learned.

2) The instructional method should be based on subject matters and associated with real life.

3) A creative work should be implemented in the 3D printing model design.

4) The instructional method should facilitate individual and collective activities of learners and encourage them to participate in debates and discussions throughout the problem-solving process.

5) The instructional method should support the mutual evaluation between learners for active feedbacks.

3.2 Developing instructional process

As in Fig. 1, traditional software development process comprises 5 stages, i.e. definition of needs, analysis, design, implementation and testing[15].

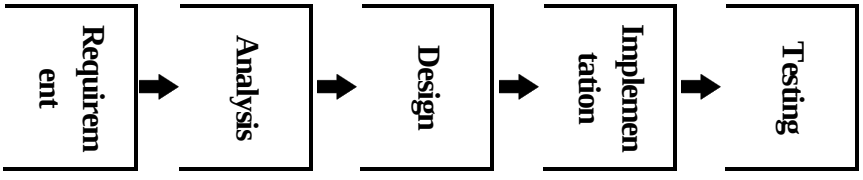


Figure 1. Traditional Software Development Process

In view of the foregoing software development process, the 3D printing modeling process first requires a stage where ideas are defined and analyzed. Fig. 2 shows a resultant procedure for learning the 3D printing, which is designed based on the first stage of definition of ideas and analysis.

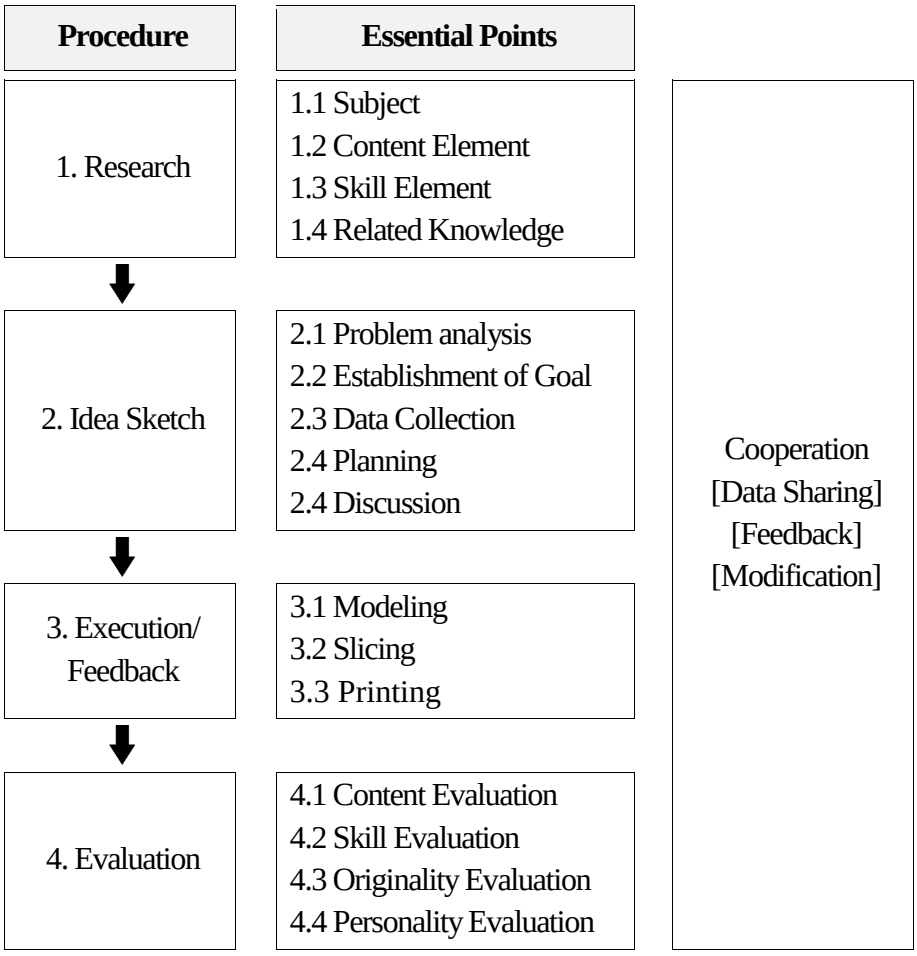


Figure 2. Learning Procedure using 3D Printer

The learning procedure for applying a 3D printer consists of four stages. First, the exploration stage largely involves the themes and contents of subject matters and the activities of exploring the components of 3D printing technology. The idea conception stage involves the analysis of problems, goal setting, data collection and planning. The key to this process is to derive creative ideas via a series of discussions. Third, the execution and feedback stage focuses on teaching the modeling, slicing and printing. The evaluation and summarization stage involves evaluating the extent to which learners meet the criteria, or the reference points in evaluation, and generalizing the results of learning.

3.3 Developing an instructional model

According to Bai Y.G.(2006), in the programming-related instructional method, the heuristic instructional model, rather than the directive instructional model, is effective for enhancing the willingness of students to engage in programming activities and their higher-level thinking skills. The heuristic instructional model is shown in Fig. 3[16].

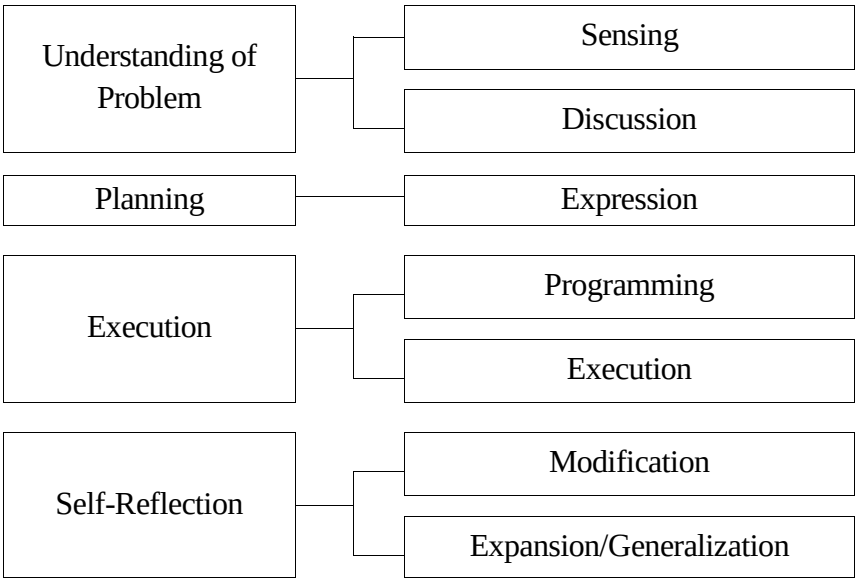


Figure 3. Learning Model

Fig. 4 shows a model for learning the 3D printing. This model is developed in accordance with the foregoing procedure for learning the 3D printing based on the instructional model.

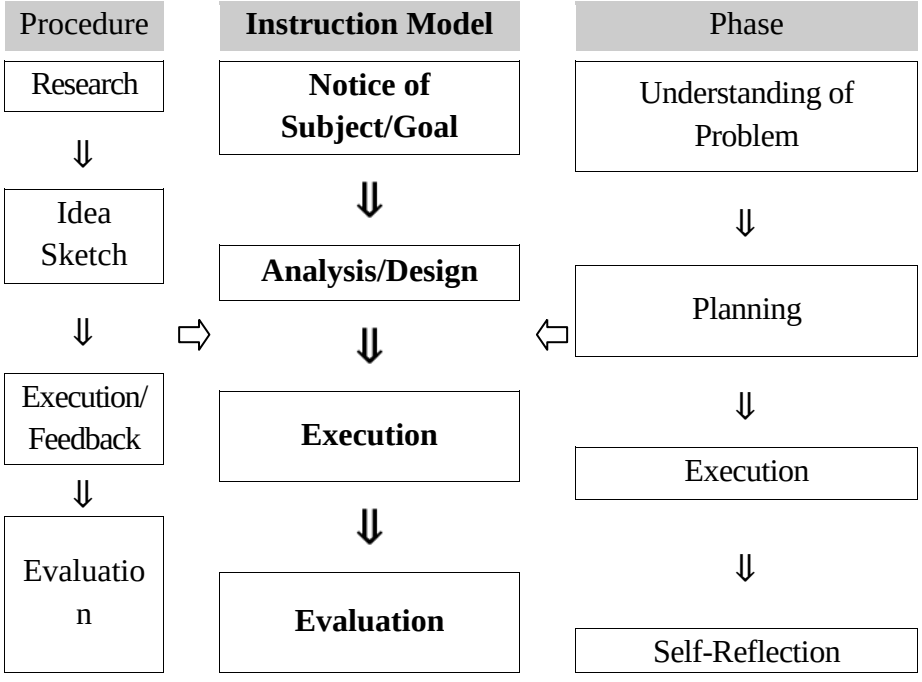


Figure 4. Learning Model for 3D Printing

In the developed learning model for 3D printing, the notice of the themes and goals of learning concerns informing learners of topics relevant to 3D printing and presenting subject matters and goals of learning the 3D printing. The analysis and design stage concerns investigating the 3D printing and generating relevant

ideas. The creation and execution stage guides learners through the modeling, slicing and printing processes for 3D printing. Finally, the evaluation stage evaluates the extent to which learners meet the learning goals of relevant activities.

4. Case Study

The present paper applies a data analysis framework to social studies. The analysis of current elementary social studies textbooks indicates that the 3D printer can be applied to such areas as general social studies, geography, and history, i.e. the start and development of our history, our livable land, our land in harmony with environment, neighboring countries' environment and lifestyles, the environment and lifestyles of many countries around the world, what we are in this changing world, where we live, our region vs. other regions, and formation of villages and life of residents.

The proposed data analysis framework consists of the notice of themes and goals of learning, analysis and design, creation and execution, and evaluation. The present chapter sequentially describes the content applied to 'Making a local symbolic icon' in social studies.

4.1 Notice of Subject/Goal

In this stage, as in Fig. 5, the subjects to be created with 3D printing are defined whilst the themes and goals of learning are presented.

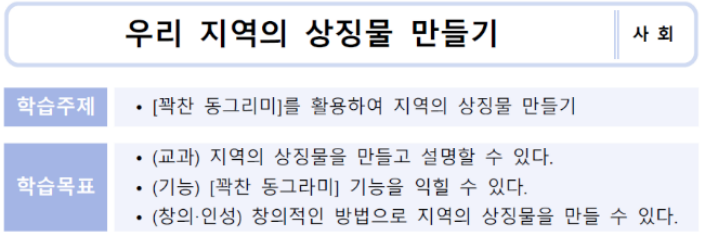


Figure 5. Notice of Subject and Goal

The themes to be learned in relation to the functional components of 3D printers are selected so that learners can learn the overall stepwise 3D printing process. Themes of the subject matter, function and creativity-personality areas are presented in conjunction with the instructional content of current curriculum as part of the learning goals.

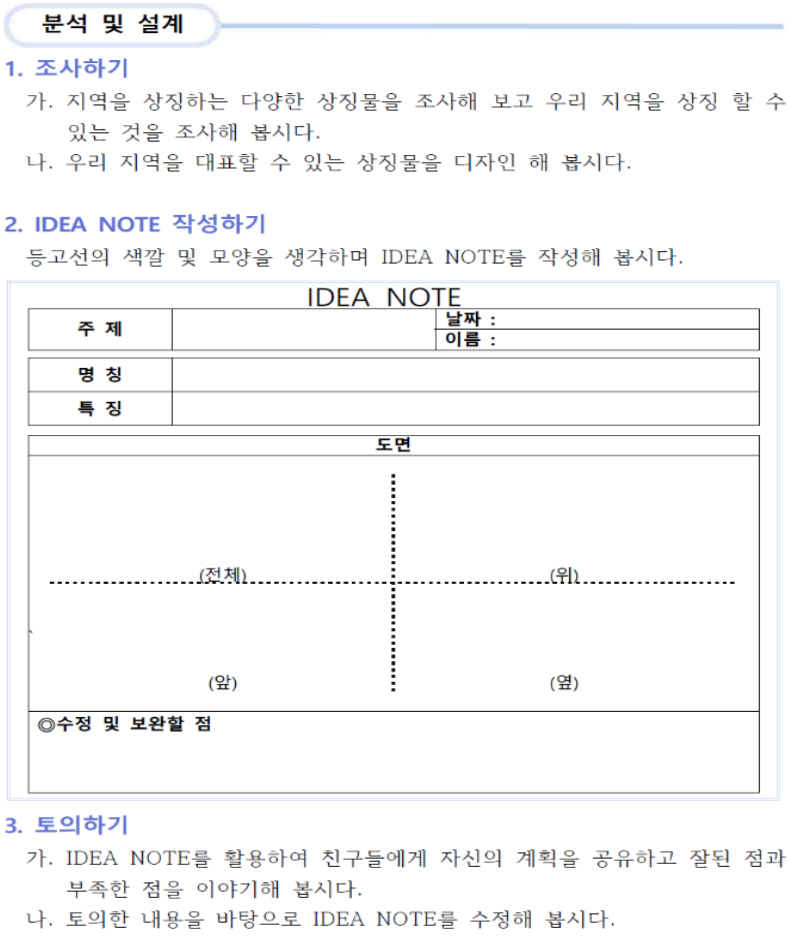
The modeling of SW functions presented as part of the learning goals is shown in Table 1.

Table 1. Function Analysis

Social Studies	4-2-3. Community development	[Move][Anchor][Color][Spin] [Square-Plus][Square-Minus] [Figure-Square][Figure-Circle] [Figure-Line]

4.2 Analysis and Design

The analysis and design stage investigates the target objects of 3D printing and develops relevant ideas. As in Fig. 6, the process involves investigation, note-taking of ideas and discussion in the order named. The investigation involves the idea conception in connection with the current curriculum with a view to learning functional components of 3D printers. As a preliminary step prior to building up a model for applying 3D printers, the note-taking of ideas involves sketching ideas and embodying thoughts. The discussion is conducted based on the individual idea note taken and the group discussion to analyze advantages and disadvantages of such ideas, which reinforces the advantages, reduces the disadvantages and improves the ideas.


분석 및 설계

1. 조사하기

가. 지역을 상징하는 다양한 상징물을 조사해 보고 우리 지역을 상징 할 수 있는 것을 조사해 봅시다.

나. 우리 지역을 대표할 수 있는 상징물을 디자인 해 봅시다.

2. IDEA NOTE 작성하기

등고선의 색깔 및 모양을 생각하며 IDEA NOTE를 작성해 봅시다.

IDEA NOTE

주 제		날짜 : 이름 :
명 칭		
특 징		

도면

(전체) (위)

(앞) (옆)

◎수정 및 보완할 점

3. 토의하기

가. IDEA NOTE를 활용하여 친구들에게 자신의 계획을 공유하고 잘된 점과 부족한 점을 이야기해 봅시다.

나. 토의한 내용을 바탕으로 IDEA NOTE를 수정해 봅시다.

Figure 6. Analysis and Design

4.3 Execution

The creation and execution stage involves modeling, discussion, slicing program setting and 3D printing in the order named to use the 3D printers.

The modeling is a process where components consisting of a real object form are converted into computer-based 3D model data as in Fig. 7.

Figure 7. Modeling for 3D printing

The discussion involves seeing, as well as discussing, a 3D virtual model of the data displayed on a computer screen. The discussion continues until the final output comes out.

The slicing program setting as in figure 8 is intended to pre-process the 3D model before the 3D printer prints out the object. The slicing process deals with the 3D model data completed by a modeling program to make a desired model by adjusting the option values of the 3D printer and transforming them into 3D model data that comprise multiple thin layers. And, in the 3D printing stage, the model data are sent to the 3D printer to print out the object.

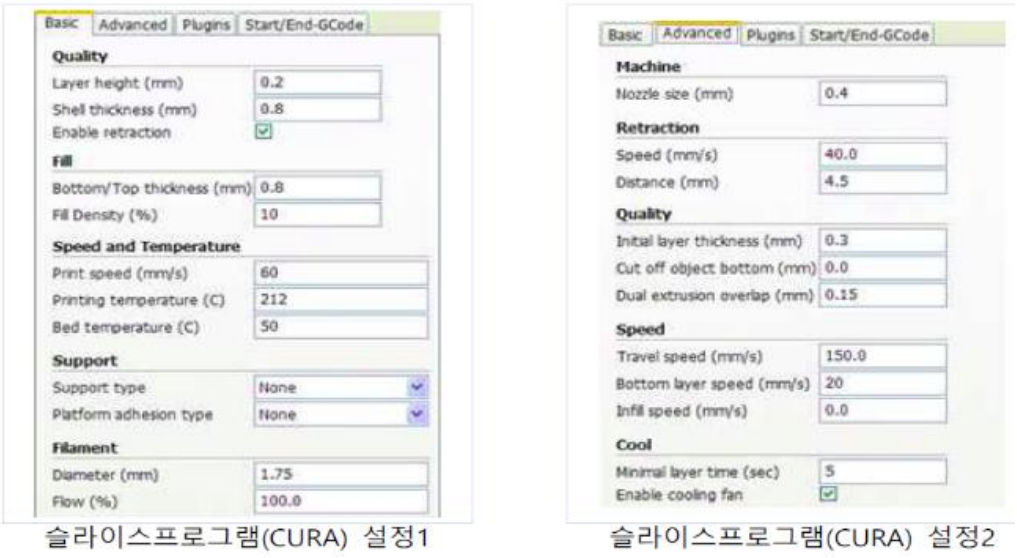


Figure 8. Slicing program setting

4.4 Evaluation

In the evaluation stage, the extent to which the learning goals of all activities are reached is evaluated. As in Fig. 9, the evaluation areas include knowledgeability, functionality, creativity and personality, with the content and method of evaluation presented for each area.

평가내용 및 방법

평가영역	평 가 내 용	평가방법
지 식	• 지역의 상징물을 만들고 설명할 수 있는가?	관찰평가
기 능	• [꽉찬 동그라미] 기능을 구현할 수 있는가?	관찰평가 IDEA NOTE
창의 · 인성	• 창의적인 아이디어가 포함되었는가?	자기평가 상호평가
	• 지역 상징물 제작 활동에 적극적으로 참여하는가?	

Figure 9. Evaluation

Based on the case of application in this paper, the knowledgeability evaluation concerns the evaluation of the components related to subject contents using the observation method. The functionality area involves the evaluation of functional components of 3D printing using the observation and idea notes. The creativity and personality area draws on the self-evaluation and mutual evaluation of the level of mutual cooperation and the willingness of learners to participate in activities.

5. Conclusion

The essence of software education is to improve the computational thinking, which refers to a computer-based problem-solving skill involving collection and analysis of data to model and implement

complicated and diverse problems in a manner that can be understood by computers. To enhance the learner's computational thinking, it is necessary to explore some instructional methods of applying 3D printers to education.

The present paper designs and applies a data analysis framework for applying the 3D printing technology to the current elementary curriculum. Learners use a workbook developed based on the proposed framework for idea development, modeling and simulation to gain some outputs printed by 3D printers. Future studies need to extend the data analysis framework to not only textbooks but also STEAM contents.

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