

Implications for Activating 3D printer Use for Education in Elementary and Secondary Schools

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Abstract— This research aims at analyzing the usage of 3D Printing in education for school grades and suggests a way to encourage schools to use 3D Printers in Education. For this, a survey was done for 3,247 teachers in Gyeonggi Province on September. Usually, schools are trying to buy 3D Printers to use it with software education courses. However, by this survey, it turns out that teachers use 3D Printer with after-school activities, creativity, and experiential activities more than regular courses. This is because there are not many teaching and learning materials for 3D Printers to be used with regular courses and it is hard for teachers to use 3D printers with professionally because lack of the training. Therefore, to activate 3D printers in schools, not only budget support but also training for teachers and developing teaching and learning materials should be involved.

Keywords— 3D Printer; new technology; usage; curriculum; education; training; learning materials.

I. INTRODUCTION

Nowadays, many schools are interested in purchasing and using 3D printers in classes to provide various experiences for students. Although the 3D printer is not developed, as a tool for education, it seems very attractive to schools in that 3D printer can provide visible output.

In addition, as the process of dealing with 3D modeling tools for students to design themselves, is regarded as a gamification factor, which can increase students' motivation, and provide enjoyable learning environment during the lecture [9]. Furthermore, if the output does not come out properly, it can also improve students' learning areas related to design, and creativity in the process of finding and solving problems, which is regarded as a problem, based learning [2].

By this recognition, the Department of Education in the United Kingdom has conducted a 3D printer project from 2012 to 2013 to explore the possibility of enriching the classroom performance with 3D printers by managing 21 pilot schools [4]

In conjunction with this, the Ministry of Science and ICT has announced a strategy for 3D printer vitalization, which includes providing 3D printers to schools in connection with software education [12], [16]. In fact, in cooperation with

the Seoul Metropolitan Office of Education, it announced plans to provide around 500 3D printers in schools and gradually expand the distribution of 3D printers in schools by 2020 [16].

In order to make good use of 3D printers in school, it is necessary to figure out the status of 3D printer utilization first and make an effort to strengthen the teacher capacity to apply 3D printer with each subject for the rapidly changing technology [10].

However, unlike these movements as mentioned above, it is difficult to see 3D printer has been activated yet. Therefore, in this study, it aims to present how to activate 3D printer usage in school in the future because of the survey on the use of the 3D printer in elementary, middle and high schools in Korea.

II. MATERIAL AND METHOD

A. Related Works

1) 3D printing and Technologies

The 3D printer can be defined as a technology, which allows the creation of physical or three-dimension objects, by digital modeling tools and additive manufacturing. As the price of 3D printers has been lowered and the possibility of

creating improvement through modeling has become magnified, there are some trials to use 3D printers in Education. Furthermore, in education, a 3D printer is regarded as a sufficient tool to apply software education, maker education, and technical subject. In particular, 3D printer, which is ICT technology can provide a means for individual and groups to develop and implement new educational ideology; it is believed to be able to play a role as a new tool for education [13]-[15].

Indeed, according to the Horizon report (2015), advances in technology can lead to innovative changes in education. Also, in the case of applied learning tools such as 3D

printing, it is said that students can create an environment in which they have a sense of ownership through learning and creative activities that they take part in. In next 2 or 3 years, it was expected that 3D printing could be spread into the educational area [8].

On the other hand, at the hypercycle in the educational field suggested by Gartner [5], a 3D printer is considered to be one of the most important technologies that can be used in school curricula [5]. According to this hypercycle, 3D printing in the classroom is at the heightened level of interest, and by 2020, 3D printer use in the classroom will become commonplace.

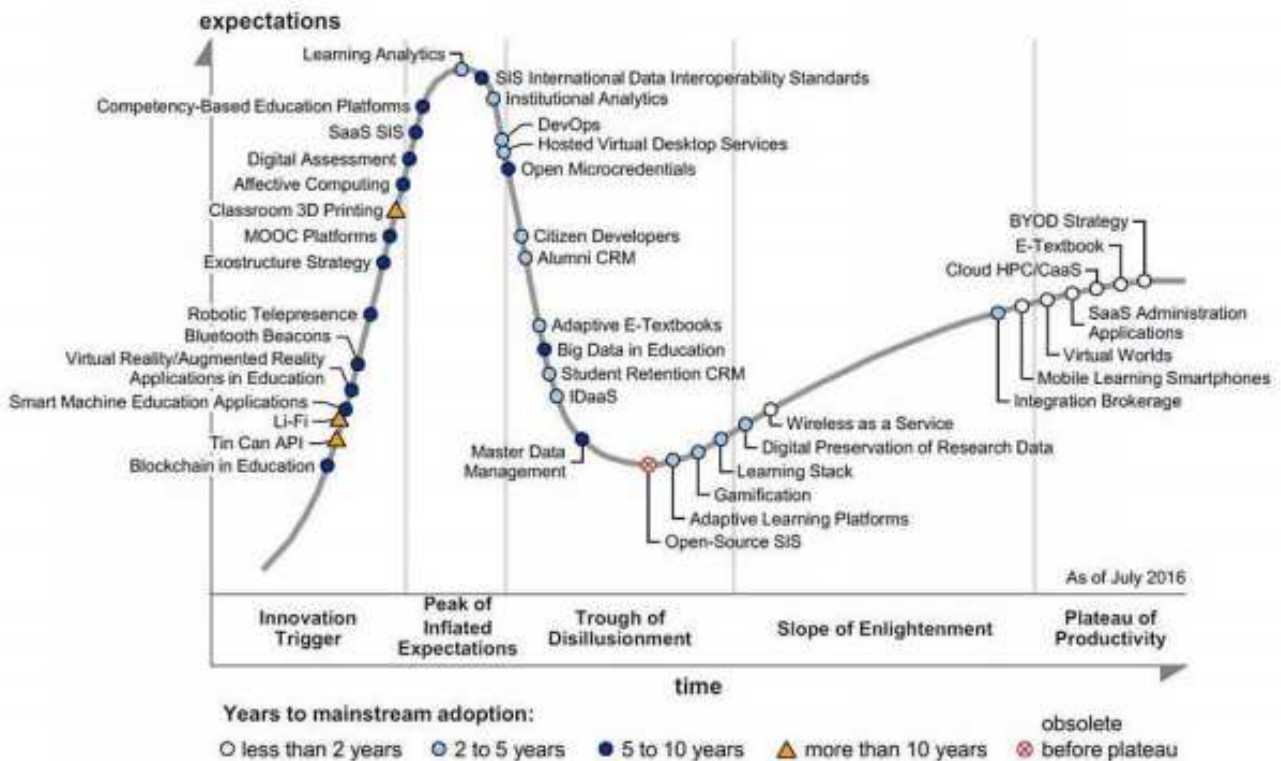


Fig. 1 Hyper Cycle of Gartner [5]

2) 3D printer in Education Related Studies

There are three main types of research related to the educational use of the 3D printer.

The first is related to the methodology and curriculum development for the application of the 3D printer to the subject, the second is teacher training for the 3D printer in school, and the last one is the effectiveness of using the 3D printer in education.

Chein (2017) suggested curriculum development in the pre-engineering curriculum for 3D printing skills for high school [3]. According to this research, STEM-oriented engineering curriculum with 3D printer and modeling helps students to do self-directed learning. As 3D printer can be used to visualize a virtual object and create visual and concrete models, it is useful for students to recognize and experience abstract concepts. In fact, in this research, the results showed that students who made output with 3D printer had higher scores than those who made hand-made works. Not only in the engineering curriculum, but also in

geoscience education, 3D printer can play a significant role in the curriculum. For example, it provides learning materials for small universe such as the moon and planet, which allows creating a library of accessible physical objects [6].

Regarding teacher training, according to the research of the Royal Academy of Engineering (2013), teachers are reluctant to apply 3D printer into the classroom because they do not understand 3D printer technology. That is why there should be a teacher training on the use of 3D printing. This paper warns that lack of training and skill is an obstacle to 3D printer activation [1]. About this, teacher training, Department of Education in the United Kingdom (2013) also mentioned that to recognize the potential of the 3D printer as an educational resource, it is necessary to share ideas regarding the competence of teachers and teacher training and technical support are required [4].

Lastly, for the effectiveness of using the 3D printer in education, there are many related studies compared to the other researches. By using 3D printers in education, students

can not only broaden their knowledge but also convey their ideas to reality. With 3D printer, the student can physically examine their outputs, and that makes students enthusiastically participate in the class, which can be effective, simulate their imagination [17]. The other research also suggested that during the modeling process, students can discuss the problem and make the necessary corrections in real time, which enable students to experience the creative interaction between peers [11]. According to RepRap 3D printer workshop in the K-12 STEM, the majority of respondents answered that 3D printer helped students understand the engineering design process and the workshop itself strengthened the ability to solve the problem of projects that previously perceived that it is beyond their skills [7].

However, those studies are not dealing with the current status of 3D printers in school, and the situation is somewhat different from Korea's one.

B. Subject of Study

This study was conducted to investigate the current status of 3D printer usage at each school level. As Gyeonggi Province is the largest among 17 provinces, it was selected as the survey target. The questionnaire was requested to cooperate with 1,227 elementary schools, 619 middle schools, and 470 high schools in Gyeonggi Province and teachers who are going to buy or use 3D printers in school or are now using it during the classes answered to the questions

C. Research Tools and Methods

The purpose of this study is to analyze how 3D printers are used at each school level and how effective and difficult it is to use 3D printers. The questionnaire was constructed by the researchers who were involved in similar papers, and the detailed contents are reconstructed in consider with a feature of this research.

The questionnaires used in this study are as follows: the first section is about personal information and backgrounds about the survey subjects, the second section includes the status of 3D printer distribution, the third section is about the effectiveness and difficulties of using 3D printers and the last part is about ways to activate 3D printers in schools. Table 1 shows the composition of the questionnaire.

TABLE I
COMPOSITION OF THE QUESTIONNAIRE

Type of Category	Questions
Status	<ul style="list-style-type: none"> • Age • Gender • Career • Presence of 3D / • 3D Printer usage in curriculum
Effectiveness	<ul style="list-style-type: none"> • The effectiveness of using 3D Printer during the classes
Difficulties	<ul style="list-style-type: none"> • Difficulties of using 3D Printer during the classes
Improvement	<ul style="list-style-type: none"> • Important elements for activating 3D printers • Governmental support to use a 3D printer

D. Research Procedure

This survey was conducted on online from September 7, 2017, to September 19 for 12 days. In this online survey, the total number of respondents was 3,247, and among them, only 529 respondents answered that they have 3D printers and use it during the classes were 529. In this survey, the answer of 529 respondents is analyzed.

III. RESULTS AND DISCUSSION

The results of the survey show how many 3D printers are equipped in each school level and how many schools use 3D printers during the classes and what kind of subjects are applying 3D printers. Also, the effectiveness of using 3D printers during the classes and the difficulties of using 3D printers in class as also analyzed. Lastly, what effort should be made to put 3D printers in schools for the better use in the future is suggested.

A. Current Status of Having and Using 3D printers

Table 2 shows the results of respondents who have 3D printers, and they use the 3D printers in their classes. According to Table 2 below, 4.6 % of elementary school teachers 16.2% of middle school teachers, and 33.2% of high school teachers answered that they have a 3D printer in Schools. It seems that the 3D printer showed the highest penetration rates in the high school. In response to the question about "Do you use 3D printers during the class?" 35.7% of elementary school teachers, 63.0% of middle school teachers and 53.9% of high school teachers were answered to their use of 3D printers for teaching. Except for elementary school, middle school and high school have more than 50% of utilization rates, but they also recorded a low figure, just over half.

TABLE II
PRESENT POSSESSION OF 3D PRINTERS IN SCHOOL
UNIT: FREQUENT (%)

	Having 3DPrinter at School	Using 3Dprinter During Class
Elementary School (Total)	4.6 (70)	35.7 (25)
Middle School (Total)	16.2 (162)	63.0 (102)
High School (Total)	33.2 (297)	53.9 (160)

B. Curriculum Using 3D printers

In table 3 below summarizes the top five subjects which teachers use 3D printer most during the classes. The detailed rankings are slightly different in each school levels; it can be said that 3D printers are applied to creative experiential activities club activities and after-school programs most. Except that courses, 3D printers are also utilized in informatics, mathematics, and technology subjects.

TABLE III
SUBJECTS USING 3D PRINTER
UNIT: FREQUENT (%)

Rank	Elementary School	Middle School	High School
1	Creative experiential activities (32.1)	Club Activities (23.6)	Club Activities (29.6)
2	Club Activities (15.1)	After School Program (21.4)	Science (14.6)
3	After School Program (13.2)	Free Semester (13.2)	After School Program (14.2)
4	Mathematics (11.3)	Technology (11.0)	Major (10.7)
5	Arts (9.4)	Informatics (9.9)	Informatics (9.9)

Although commonly answered subjects such as creative experiential activities, club activities, and after-school program are also organized in regular class time, it is more likely to be regarded as an autonomic subject rather than a regular course. In other words, it is still not easy to utilize 3D printers for regular courses such as mathematics, sciences technology and so on.



Fig. 2 Free semester activities using 3D Printer



Fig. 3 Class output by using 3D Printer

C. Effectiveness and Difficulties of Using 3D printers

1) *The effectiveness of Using 3D printers During the Class:* In response to the question that what is the effect of using 3D printers during the classes, respondents answered in order of providing diverse learning experiences, increasing creativity and problem-solving ability, enlarging educational opportunities, enhancing the autonomy of learners.

This study found that there is no significant difference between the results of each school levels. In elementary school, increasing creativity and problem-solving ability got the most choice. However, in the case of high school, providing various teaching and learning experiences and increasing creativity and problem-solving ability showed the same response. The detailed results are given in Table 4.

TABLE IV
THE EFFECTIVENESS OF USING 3D PRINTERS DURING THE CLASS
UNIT: FREQUENT (%)

Effectiveness	Elementary School	Middle School	High School	Total
Diverse Teaching and Learning Experiences	9 (36.0)	40 (39.2)	57 (35.6)	106 (36.9)
Enlarge Educational Opportunities	1 (4.0)	16 (15.7)	25 (15.6)	42 (14.6)
Develop Creativity and Problem Solving Capability	12 (48.0)	33 (32.4)	57 (35.6)	102 (35.5)
Autonomy of Learners	2 (8.)	9 (8.8)	12 (7.5)	23 (8.0)
Etc	1 (4.0)	4 (3.9)	9 (5.6)	14 (4.9)

$$\chi^2 = 4.274, P > 0.05$$

2) Difficulties in Using 3D printers in Class

Table 5 shows the results of the difficulties in using the 3D printer in the classroom. In the results of total, which did not distinguish between each school levels, the highest response rates were expensive equipment cost (37.3%), followed by lack of professional manpower (24.7%), lack of teaching and learning materials(17.1%), equipment maintenance cost (15.3%) and repair cost(5.6%) were occupied.

Unlike the result of each school level, about the effectiveness of using 3D printers during the class, the answer to the difficulties of using the 3D printer in class showed almost the same in each school level.

TABLE V
DIFFICULTIES IN USING 3D PRINTERS IN CLASS
UNIT: FREQUENT (%)

Difficulty	Elementary School	Middle School	High School	Total
Expensive Equipment Cost	9 (36.0)	40 (39.2)	58 (36.3)	107 (37.3)
Equipment Maintenance Cost	3 (12.0)	17 (16.7)	24 (15.0)	44 (15.3)
Repairing Cost	2 (8.0)	5 (4.9)	9 (5.6)	16 (5.6)
Professional Manpower	6 (24.0)	18 (17.6)	47 (29.4)	71 (24.7)
Lack of Teaching and Learning Materials	5 (20.0)	22 (21.6)	22 (13.8)	49 (17.1)

$$\chi^2 = 6.654, P > 0.05$$

D. Ways to Activate 3D printers in School

1) *Essential Things to Activate 3D printer*: Teachers who are using 3D printers in their current classroom are asked to rank six options, which should be the top priority. The responses are shown in Table 6 below. Although answers of each school level did not match the rankings, most respondents cited 3D printer budget support, 3D printer utilizes training, providing teaching and learning materials as an essential support for 3D printer activation in schools.

TABLE VI
THE WAY TO ACTIVATE 3D PRINTER FOR TEACHERS (AVERAGE)

Category	Elementary School	Middle School	High School
3D Printer Utilization Training	3.04	2.67	2.63
Dissemination of Teaching-Learning materials	3.28	2.83	3.06
Sharing use cases of other schools	4.2	4.09	4.34
Deploying personnel to maintain 3D Printers	3.92	4.63	4.06
Deploying 3D Printer Professionals	3.92	4.39	4.14
3D Printer Budget support	2.64	2.66	2.78

Table 6 above represents the mean value of the responses divided by the total respondents; Table 7 shows the results of the first choice responses selected by each school level.

Similar to Table 6 above, it can be seen that providing 3D printer training, supporting 3D printer budget support and

developing teaching and learning materials were selected as the first choice.

TABLE VII
THE WAY TO REVITALIZE 3D PRINTER FOR TEACHERS
UNIT: FREQUENT (%)

Category	Elementary School	Middle School	High School
3D Printer Utilization Training	4(16.0)	30(29.4)	53(33.1)
Dissemination of Teaching-Learning materials	4(16.0)	14(13.7)	18(11.3)
Sharing use cases of other schools	1(4.0)	4(3.9)	4(2.5)
Deploying personnel to maintain 3D Printers	1(4.0)	2(2.0)	14(8.8)
Deploying 3D Printer Professionals	3(12.0)	3(2.9)	10(6.3)
3D Printer Budget support	12(48.0)	48(47.1)	61(38.1)
Total	25(100)	102(100)	160(100)

Although budget support for a 3D printer is generally high, in order to use 3D printer more efficiently, in addition to budgeting for a 3D printer, it can be said that it must be accompanied by operating appropriate training for teachers and spread of related teaching and learning materials.

2) *Administrative Support to Activate 3D printers*: In addition to the essential things to activate 3D printer utilization, respondents answered the question that the administrative support that government department such as the ministry of science and ICT, the ministry of education should provide. In the results, it shows that support of purchasing 3D printer budget is overwhelmingly high and teacher training and 3D printer manpower support is followed.

As ministries are usually in charge of budgeting and training, respondents suggested that in order to activate the 3D printer, it is necessary to secure budgets for the supply of equipment and to train teachers to become specialists who can handle the 3D printers and its modeling tools.

On the other hand, the answer to the development and dissemination of the teaching and learning materials was relatively low, unlike the survey results above. It can be said that this is because, after receiving 3D printer training, it is possible for teachers to make teaching and learning materials by themselves. This suggests that rather than producing state-led class materials, it is preferable to acquire teaching and learning materials by each curriculum and instructional tendency.

TABLE VIII
ADMINISTRATIVE SUPPORT TO ACTIVATE 3D PRINTERS
UNIT: FREQUENT (%)

Category	Elementary School	Middle School	High School
Budget Support for buying 3DPrinters	15(60.0)	58(58.0)	81(50.6)
Training Program for Teachers	3(12.0)	26(26.0)	35(21.9)
Personnel for Maintenance of 3DPrinters	2(8.0)	5(5.0)	14(8.8)
Experts for using 3D Printers	4(16.0)	7(7.0)	20(12.5)
Developing 3DPrinter using materials	1(4.0)	4(4.0)	10(6.3)
Total	25(100)	100(100)	160(100)

$$\chi^2 = 6.837, P > 0.05$$

IV. CONCLUSIONS

It is true that in order for the 3D printer to be active in schools, there must be enough budget support to buy a 3D printer at the school. However, just buying a 3D printer, without a skilled teacher to handle it, a 3D printer can become useless. It was found through the survey that reasonably high percentage of schools do not use the 3D printer even though school is equipped with 3D printers to use.

Also, respondents answered that they use 3D printers in class, but the most of the subjects ranked to upper classes were somewhat inappropriate to say that they were regarded as regular courses. This is a result of lack of sufficient teaching and learning materials to use the 3D printer in conjunction with regular curriculum and lack of professional teachers (or lack of training for teachers) to handle curriculum and 3D printer at the same time.

Therefore, in order to popularize 3D printer in school shortly, it should be accompanied by the development and dissemination of diverse teaching and learning materials that can be applied to the class as well as teacher training that can cultivate teacher of talent in using 3D printers.

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