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The Development and Application of the Augmented Reality Based STEAM Education Program: Based on the Inquiry Learning Model

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Abstract

The purpose of this study is to develop an education program that can increase the effect of learning, and provide a more systematic and practical problem solving procedure for inquiry activities by enhancing learner's context awareness of the learning scene, sense of reality and immersion using augmented reality technology. Accordingly, on the basis of literature review and case analysis, an augmented reality based STEAM education program founded on the model of inquiry learning model was suggested. For the verification of effectiveness, the program was applied to the field among grade 6 students living in Seoul. As a result, this paper demonstrates not only the significance of the development of STEAM education program using augmented reality based textbook but also the significance of the augmented reality based STEAM education program founded on the inquiry learning model. It also verified the effectiveness of the augmented reality based STEAM education program on the cultivation of active inquiry learning ability.

Keywords: STEAM Education, Augmented Reality, Inquiry Learning Model

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1. Introduction

We are facing a new digital era along with the rapid development and changes in information and communication technology. Augmented reality, which presents

information of the virtual world to the real world, maximizes learning interest and immersion (concentration) by providing experiences of experimental learning to learners, allowing them to use experimental tools, presented as virtual objects, directly with their hands.

Also, STEAM is a new tendency, a driving force for the innovation of future education systems, and a new form of smart education that converged science, technology, engineering, arts and mathematics. It is an educational approach that not only enhances individual knowledge transfer ability and creativity but also allows practical connection with the cutting edge science and technology world. On the other hand, inquiry learning allows learners to understand the experiment results through the inquiry process of 'problem understanding – setting up hypothesis – experimental design and implementation – hypothesis verification – drawing conclusion.' However, as a systematic teaching method, it is inadequate in suggesting valid grounds for the processing of experimental results and hypothesis verification. Therefore, based on this perspective, it is necessary to have a new systematic education program that can enhance the capacities of learners and successfully verify causes and results.

In this context, the purpose of this research is to develop a meaningful STEAM education program that goes beyond the conventional learning methods that mainly depended on experimental activities. The education program developed in this research enhances context awareness using augmented reality technology, and allows learners to experience a systematic and practical problem solving process in inquiry activity.

2.Theoretical Background

2.1. STEAM Education

STEAM education is an educational policy that awakens the creativity and emotions of students by adding Arts to STEM (Science, Technology, Engineering, and Mathematics) education, which was implemented since the 1990s in the United States with the purpose of strengthening the education on mathematics, science, engineering and technology in order to nurture future human resources for the science and technology sector. The purpose of STEAM education is to nurture creative human resources in the science and technology sector by increasing students' interests on mathematics, science, and engineering technology.

2.2. Utilization of Augmented Reality Technology in Education

It has become easier to utilize augmented reality display devices in school education field with the recent increase in supply of smart phone devices. Moreover, as it is easy to produce the marker through printouts, there are various attempts to create educational contents based on augmented reality as supplementary teaching materials.

ⓐ Borrero and Márquez (2001) compared the remote lab educational effect of augmented reality environment lab, virtual environment lab, and real classroom environment lab and found that the augmented reality lab had the highest educational effect. Thus they argued that augmented reality can become a new method for e-learning.

ⓑ Ko and Kim (2012) developed an augmented reality combined marker system, which is composed of a combination of augmented reality objects. They designed the lessons using 'Earth and Moon' of grade 5 elementary science as the learning contents. The results implied that the contents had significant impact on knowledge and practice, which are the main factors that determine the level of academic achievement.

In this sense, as educational contents based on augmented reality technology have the advantages of providing practical tasks and enhancing self-directed learning and problem solving ability, there is a need to develop augmented reality-based contents and learning programs not only for a certain field but also for STEAM convergence education.

2.3.Application of Suchman's Inquiry Learning Model

As learners have the basic desire to inquire, it is necessary to assist leaners to raise questions, train and develop intellectually, which is necessary to find answers. Therefore, as the ultimate purpose of inquiry instruction is to offer the experience of knowledge creation to students, curiosity in intellectual inquiry must be based on ideas that are possible to discover. The teaching and learning steps of inquiry instruction are composed of 5 steps and <Figure.1> summarizes steps of the model.

① Confronting the problem situation	→	▪Explain the inquiry process ▪Present the situation with ambiguity
② Confirming the problem and data	→	▪Confirm the essence of objects and conditions ▪Confirm the occurrence of problem situation
③ Collecting data and experimenting	→	▪Define the related variables ▪Set or verify hypothesis with causal relationship
④ Explaining the inquiry results	→	▪Explain and organize principles or results
⑤ Analyzing the inquiry process	→	▪Analyze inquiry strategies ▪Develop a more effective strategy

[Figure. 1] Steps of Suchman's Inquiry Learning Model

3. Education Program and Validity Test

3.1. Learning Direction and Learning Contents of the Program

As the selection of appropriate learning contents should be precedent to deliver an effective lesson, the learning directions were established as follows: First, the program not only offers experiences of the extensibility of cutting-edge technology and scientific principles related to augmented reality experience, and just-in-time learning but also connects the educational contents to real pending issues. Second, by selecting the main subject of the program based on prominent people and their achievements, the research designed a subject oriented course that requires an integrated approach from various fields, and allowed integrated understanding by

applying basic concepts of science and the current application of technology. Third, the research examined the ways to apply the contents from the real curriculum, by analyzing the curriculum of various fields for integrated education and selecting the subjects applicable to the class model.

The learning contents as in the chapter of ecosystem, environment and environmental protection, includes various fields such as science, social studies, and arts. This provides a convergence class approach on a theme with an integrated perspective. Moreover, the program not only allows learners to observe the virtual ecosystem and analyze the ecosystem structure using the augmented reality technology, but also provides experiences of cooperative problem-solving as a group in the stage of producing results.

3.2 .Development of the Education Program

This program was structured into 5 stages of inquiry process: Learners collect information and confirm, identify concepts, set up hypotheses, verify, and solve the problem.

[Table 1] Education Program 1. Darwin's Galapagos Expedition

<table>
<tr><th></th><th>STEAM Steps</th><th>Suchman's Learning Model</th><th colspan="3">Contents</th></tr>
<tr><td rowspan="5">1</td><td rowspan="5">Presentation of Situation</td><td rowspan="2">Confronting the problem situation</td><td>Related Course</td><td>Science (Ecosystem and Environment)</td><td>S</td></tr>
<tr><td colspan="3">►Observe various living things Darwin encountered, through video clip
►Arouse curiosity regarding the characteristics of living things that appear in order to adapt to the environment, and explain the inquiry process</td></tr>
<tr><td rowspan="3">Confirming the problem and data</td><td>Related Course</td><td>Science (Ecosystem and Environment)</td><td>S,T,A</td></tr>
<tr><td colspan="3">►Understand the process of how Darwin established the evolution theory through the Galapagos expedition
►Understand <augmented reality> and application utilization methods</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Creative Design</td><td>Related Course</td><td>Science (Ecosystem and Environment)</td><td>S,T,E,A</td></tr>
<tr><td colspan="3">►Explore images → Explore the environmental adaptation of living things → Classification of information</td></tr>
<tr><td>3</td><td>Creative Design</td><td>Collecting data and</td><td>Related Course</td><td>Science (Ecosystem and Environment)</td><td>S,T,A</td></tr>
</table>

		experimenting	►Understand evolution principles that are related to the relationship of natural environment and living things ►<Augmented reality: combining markers> Observe the cases of ecological adaptation of animals and plants caused by changes in the natural environment → Observe the different features of the birds which change depending on the different combinations of Bird + Food + Natural Environment markers		
4	Emotional Experience		Related Course	Science (Ecosystem and Environment)	**S,T,A**
			►<Augmented reality: using maps> understand the ecosystem through observation of virtual island → Record and collect features of the natural environment by exploring the augmented reality map		
		Explaining the inquiry results	Related Course	Science (Ecosystem and Environment)	**S**
			► Create a structure map based on the understanding of ecosystems ► Organize the results and make group presentation based on the analysis of the information collected in the previous step		
		Analyzing the inquiry process	Related Course	Science (Ecosystem and Environment)	**S**
			►Organize the contents and make reflections → Discuss what you have felt and learned		

[Table 2] Education Program 2. Making Public Service Posters for Ecosystem Protection

	STEAM Steps	**Suchman's Learning Model**	**Contents**		
1	Presentation of Situation	Confronting the problem situation	Related Course	Social studies (Human beings living in harmony with nature) Social studies (Efforts to solve environmental problems)	**S**

			►Study on the effect of environmental changes on animals and plants ►Design posters for public service related to environmental protection → Manage the problem situation actively → Learn the methods of message delivery through experience ►Explain the inquiry process		
	Creative Design	Confirming the problem and data	Related Course	Social studies (Human beings living in harmony with nature) Social studies (Efforts to solve environmental problems)	**S,T,E, A**
			►Reissue the marker cards used in program 1 ►<Augmented reality: Combining markers> Examine the changes in features of the birds followed by the changes in the environment and food ►Infer the answers based on what students have learned previously → Arrange on the map ►Select one type of bird, and write a report on how to protect the ecological environment of the selected bird		
2	Emotional Experience	Collecting data and experimenting	Related Course	Arts (Protect the nature)	**S,T,E**
			►Watch various cases of public service advertisements ►Based on the ecosystem → Create a public service poster for environmental protection campaign, in groups		
3	Emotional Experience		Related Course	Arts (Protect the nature)	**S,T,E**
			►<Augmented Reality: Augment visual image with the Aurasma app> Film students stating the advertisement message created, with a smart phone → film the posters created individually → Link the filmed video clip to augment using the Aurasma app		
		Explaining the inquiry results	Related Course	Arts (Protect the nature)	**S,T,E, A**
			►Present the advertisements in groups		
		Analyzing the inquiry process	Related Course	Arts (Protect the nature)	**S**
			►Listen to the presentations on advertisements → Select the best advertisement → Make presentation on making process of the advertisement		

3.3 Expert Validity Test and Results

For validation, the education program and learning contents were examined by three STEAM experts and they verified the validity based on the question how

appropriately the augmented reality was applied to each steps of the inquiry learning model.

[Table 3] Education program 1,2. Expert Validity Test Methods and Results

►Composition of Experts : 1 expert with five years of STEAM development experience / 1 expert with four years career / 1 middle school teacher
►Investigation Method : 5-point Likert Scale method / email survey method and face-to-face interview method

Application of Suchmans' Inquiry Learning Model	Program 1	Program 2
1. Confronting the problem situation	3.66	3.66
2. Confirming the problem and data	4.33	5
3. Collecting data and experimenting	5	4.66
4. Explaining the inquiry results	3.66	4
5. Analyzing the inquiry process	4	4.33
Total	**4.13**	**4.33**

The expert opinions on the STEAM education program are as follows. First, in the stage of 'confronting the problem situation', experts commented that there is a need to suggest a more detailed situation in order to encourage self-thinking. Second, one class is not enough for 'collecting data and experimenting' and it should be given more time. Based on these comments, in order to suggest a more detailed situation a video clip on various living things and various examples of public service posters were added. Also the time allocated for producing the public service advertisements was expanded adding one more class.

4. Application of Program and Analysis

4.1. Subject of Field Application of Program and Application Method

[Table 4] Subject of Application and Method

►Subject	Grade 6 Students of 'K' Elementary School, Gwangjin-gu, Seoul
►Date	November 28, 2014
►Contents	Science 4. The ecosystem and the environment (Refer to Program 1,2)
►Teaching Methods	Education program applying the inquiry learning model based on augmented reality
►Application Methods	Instructions → Class and experiment → Survey on learners' response

The research experimented the utilization of augmented reality on the 2009 curriculum of grade 6 1st semester of science 4. The course was divided into seven times. First, in the 'confronting the problem situation' stage, the program ① suggested video clip on various living things → ② increased curiosity → ③ made the students individually think about the characteristics of the various living things suggested in the video clip regarding to how they adapted to the environment. Next, after explaining the introduction of the inquiry process; in the 'confirming the problem and data' stage and 'collecting data and experimenting' stage, ④ make the students personally control (place and arrange each markers on the designated places) the augmented reality contents developed →⑤ learn through experience of observing the changes in the birds depending on different conditions. The experiment was made as a pair activity. Each person was to decide a role, conduct the experiment and produce a study paper. For the study contents based on the experiment, learners go through the stages of 'explaining inquiry results' and 'analyzing inquiry process. At the end, a survey was conducted to examine learners' response.

4.2.Analyzed Results

The survey results on learners regarding the class experience are as follows.

[Table 5] General Tendency of Class Satisfaction (N=50 *The higher the score, the higher the satisfaction)

	Mini.	Max.	Mean	SD
Science class has become more amusing than before	1	5	3.74	.853
My understanding of science and maths increased	1	5	3.90	.707
I have become more interested in science and maths than before	1	5	3.84	.889
I have become more interested in science technology than before	1	5	3.96	.880
I like reading science books and writings more than before	1	5	3.30	.909
I can think of my own to solve a problem	1	5	3.90	.814
I can finish various learning activities not giving up on the way	1	5	4.00	.782
I encounter a problem from various perspectives	1	5	3.88	.659
I try to associate what I have learned with real life	1	5	3.74	.899
I try to apply what I have learned about problem solving in life	1	5	4.16	.650
I participate in class more actively than before	1	5	4.34	.823
I discuss with my friends more rationally	1	5	4.22	.840
I express my ideas to friends	1	5	4.44	.675
I listen and respect the opinions of others	1	5	4.08	.752

I understand the importance of cooperating with others	1	5	4.26	.694
I have become more considerate to others than before	1	5	4.18	.661
I do not fear failure and accept challenges	1	5	4.12	.659
I am more interested in jobs related to science and technology than before	1	5	3.46	1.014
Total class satisfaction	**1**	**5**	**3.97**	**.431**

The general tendency of class satisfaction was above the midpoint with the total class satisfaction scoring 3.97 out of 5. To examine each items, items such as 'I express my ideas to friends' was 4.44 out of 5; 'I participate in class more actively than before' was 4.34; and 'I understand the importance of cooperating with others' was 4.26, showing relatively high scores. On the other hand, items such as 'I like reading science books and writings more than before' was 3.30; and 'I am more interested in jobs related to science and technology than before' was 3.46, showing relatively low scores. Also, all items showed scores higher than 3 out of 5, higher than the midpoint

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[Table 6] The Level of STEAM Class

		Very Easy	Somewhat Easy	Normal	Total	X^2 (p)
Sex	Female	4	14	7	25	.889
		16.0%	56.0%	28.0%	100.0%	(.641)
	Male	4	11	10	25	
		16.0%	44.0%	40.0%	100.0%	
Total		8	25	17	50	
		16.0%	50.0%	34.0%	100.0%	

To examine the level of STEAM class, about 66% of the students answered 'very easy' or 'somewhat easy', which is higher than the 34%, who answered 'normal.' About 72% of the female students answered 'very easy' or 'somewhat easy', and for male students, about 60%. Overall, the percentage of female students, who responded that the level of STEAM class they participated in was easy, was higher than that of male students, but there was no statistically significant difference.

[Table 7] The Interest Level of STREAM Class

		Very Interesting	Somewhat Interesting	Normal	Not Interesting	Total	X^2 (p)
Sex	Female	8	11	4	2	25	5.670
		32.0%	44.0%	16.0%	8.0%	100.0%	(.129)
	Male	3	17	5	0	25	
		12.0%	68.0%	20.0%	.0%	100.0%	
Total		11	28	9	2	50	
		22.0%	56.0%	18.0%	4.0%	100.0%	

Also, compared to about 4% of the students who have answered that 'the class was not interesting (amusing) at all' or 'the class was not interesting (amusing) most of the time', about 78% of the students answered positively that 'the class was very interesting (amusing)' or 'the class was interesting (amusing) most of the time'. About 76% of the female students positively answered 'very interesting' or 'somewhat interesting', whereas about 80% of the male students responded positively. Male students showed a higher level of interest in the STEAM class they participated in, than female students; however, there was no statistically significant difference.

[Table 8] Willingness to Attend STEAM Classes

		Strongly Agree	Agree	Normal	Disagree	Total	X^2 (p)
Sex	Female	6	12	7	0	25	3.071
		24.0%	48.0%	28.0%	.0%	100.0%	(.381)
	Male	3	10	11	1	25	
		12.0%	40.0%	44.0%	4.0%	100.0%	
Total		9	22	18	1	50	
		18.0%	44.0%	36.0%	2.0%	100.0%	

For the question asking whether they want to continue attending STEAM classes or not, about 62% positively answered 'strongly agree' or 'agree' while about 2% answered 'strongly disagree' or 'disagree'. About 72% of the female students positively answered 'strongly agree' or 'agree', whereas 52% of the male students responded positively. Female students were more willing to continue to take STEAM classes than male students; however, there was no significant difference, statistically.

Meanwhile, participants pointed out that 'there are many group activities that require cooperation with others' (34.0%), as the biggest difference between the STEAM classes and conventional classes. The weaknesses pointed out were: shortage of time (52.0%), conflict during discussions (34.0%), high difficulty of the problem (6.0%), and difficulty in understanding the contents (4.0%).

5. Conclusion

5.1. Results

This research utilized augmented reality technology, a cutting edge technology, so applying to direct experiences, and made practical applications in field education. Unlike the conventional subject of education, it approached with an integrated perspective of various fields. Also, this research developed a STEAM education program analyzing science, social science, and arts as convergence education. Moreover, Suchman's inquiry learning model was applied to the program and through validity verification by experts the program was modified. By demonstrating the class in the educational field, the program was further improved.

As a result of field application, the significance of the STEAM education program applying the inquiry learning model based on augmented reality was proven. Also the analyzed results showed that the program significantly improved learners' active inquiry learning capacities. Also, it was able to increase motivations and interests of students as the program makes the students cooperate, experiment and experience in groups. Through this process, students easily acquired various knowledge related to the educational principles included in the curriculum.

5.2. Limitations and future suggestions

Although the expert validity test modified the program (adding class time), there were additional comments that there was a lack of time for research, practice, and making. Therefore there is a need to take complementary measures regarding the time allocation. Moreover, although the STEAM education program suggested in this research has been structured to increase the interests of elementary school students, the period of education is very short and there are concerns that the increase in interest will be a temporary phenomenon. Therefore, it requires further research to complement the weakness and modify the program.

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