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Investigation of the Relationships between Media Characteristics, Presence, Flow, and Learning Effects in Augmented Reality Based Learning

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This study's goal is to examine which factors of augmented reality (AR), the fruit of future technologies, help to improve learning effects, and to reveal the relationships between those factors. To this end, we examined previous studies and selected five factors that can influence learning effects in augmented reality based learning. We discovered the effectiveness structure of media utilization in augmented reality based learning through an investigation of the relationships between those factors. The five factors selected were: sensory immersion, navigation, manipulation, presence, and flow. A questionnaire was formed based on these research questions, and a survey was conducted on 290 fifth-graders at two elementary schools. A total of 272 cases were examined for this study (incomplete and unreliable responses were excluded) and these were analyzed using a structural equation model. The results showed that with the exception of navigation, all factors such as sensory immersion, manipulation, presence, and flow had a meaningful influence on satisfaction, knowledge & understanding, and learning effects of application. In particular, the manipulation factor was proven to have a direct effect on satisfaction and the application aspect of learning effects, indicating that strengthening manipulation through the tangible interface of augmented reality can be an important factor in the areas of learning satisfaction and application. In addition, sensory immersion was proven to have a meaningful influence on immersion in learning and learning effects. In terms of learning effects, the application of augmented reality media was shown to have a greater influence on application factors than on knowledge & understanding.

Keywords: augmented reality (AR), immersion, manipulation, navigation, presence, flow, learning effect, structural equation model (SEM)

INTRODUCTION

Media has been an object of interest even before the emergence of advanced types of media, and efforts have been continuously made to link media with education. Thanks to the development of computer technology, the fundamental question of, "Will media improve education?" has now expanded into a different question: "How will technology change education?" (Banathy, 1991: Reigeluth, 1991). The main area of concern for media researchers, however, still lies in the effectiveness of the teaching media (Kim, et al., 2006; Na, 1994). Despite expectations that media can increase the interest or attention of learners by providing a greater variety of information, it is difficult to find specific studies that examine how media improves learning effects, or which features of media are related to learning activities.

This study's goal is to examine which factors of augmented reality (AR), the fruit of future technologies, help to improve learning effects, and to reveal the relationships between those factors. This study examines the relations between those factors based on the following aspects.

First, this study, by separating sensory immersion through audio-visual effects from flow, aimed to examine whether augmented reality's sensory immersion effect would lead to actual immersion in the learning contents and courses and ultimately, to learning effects.

Second, in terms of the cognitive aspect of learning effects, we separated the acquisition of knowledge from the aspects of understanding & application for this study. Augmented reality technology, which tends to enhance circumstances and context through a combination of reality and virtual reality, is expected to have an effect not only on the acquisition and understanding of simple concepts, but also on the application of knowledge by expanding the scope of learning (Ryu Ji-hyeon, et al., 2006). Therefore, this study examined whether augmented reality based learning can be meaningfully utilized, not in the acquisition of de-contextualized knowledge, but in the actual context of knowledge application.

THEORETICAL BACKGROUND

Augmented reality

Augmented reality (AR) is a technology that provides a more advanced sense of absorption and reality for users by seamlessly combining the real world with the virtual world in real time (Azuma, 1997). Both virtual reality and augmented reality are based on virtuality. Augmented reality is located in the middle, between reality-based media and virtual reality, which allows users to become completely immersed in a computer-created virtual location. Augmented reality also increases the user's sense of reality, by adding virtual information to his or her real environment. Augmented reality technology differs from virtual reality technology (which completely replaces a real environment with a virtual reality) in that it maintains the information of the user's real environment. Figure 1 displays the position of augmented reality on the continuum between real and virtual environments.

Since Mark Weiser's article on visions of "Ubiquitous Computing" was published in 1991, the world has been rapidly moving toward a new paradigm that makes technology invisible. In order for computers to become ubiquitous and invisible, a union between the physical environment and digital information is essential, along with the provision of a tangible manipulation method that is superior to the existing graphic user interface (GUI) (Ishii & Ullmer, 1997). Augmented reality is a three-dimensional medium that supports such a tangible interface, and enables a seamless interaction between people and information.

Presence

Marvin Minsky, a professor of artificial intelligence at MIT, was the first scholar to show an interest in presence theory (1979). The definition of presence varies among researchers, but it can be divided into the following two parts, with a perceptual concept as its common basis. The first part is a condition whereby people, when experiencing something that is presented through a given media, do not recognize the existence of said media. People who do not recognize the media itself when watching TV or movies are a case in point. The second part is a sense of "being there", in which people feel as though they are together with the media, even when they are somewhere else. Presence is classified in different ways by different scholars. Heeter (1992) classified presence into three aspects, positing that there was a subjective personal presence, a social presence, and an environmental presence. He argued that subjective personal presence was important, given that recognizing one's self is a primary issue, not only in the real world but also in virtual reality. He also argued that social presence was a necessary next stage, enabling people to recognize the existence of others, and, for the final stage, the environmental presence of virtual reality, which enables people to react as if they were in the real world, enhances presence.

This study, based on these discussions about presence, defines presence as a cognitive condition in which people in an augmented reality environment feel virtual objects in a real world. In contrast, presence in virtual reality is the cognitive condition in which people feel that "I am in a virtual reality." This differs from the presence of augmented reality, in which people actually feel that "there are virtual objects in the real world where I am."

Flow

When factors, such as technologies or challenges, reach a certain level as people are engaged in the various activities undertaken in their daily lives, people become engrossed in them. Flow is the condition in which people feel the present experience as an optimum experience of complete absorption. This concept was first presented in a paper titled “Beyond Boredom and Anxiety”, which was written by Csikszentmihalyi in 1975. He argued that absorption is a psychological and physical energization that people feel when they are completely absorbed in their activities. He also maintained that when a difficult task is combined with a high level of competence, in-depth participation and optimal absorption are achieved, which is difficult to attain in the real world. Flow is a result of successive reactions stimulated by interactions, and it is essentially interesting and accompanies a complete loss of self-consciousness. Also, it is characterized by voluntary reinforcement (Novak & Hoffman, 1996).

Flow has the following nine characteristics: (1) clear goals (2) immediate feedback (3) balance between challenge and skill level (4) concentration on the task at hand (5) action-awareness merging (6) loss of self-consciousness (7) altered sense of time (8) sense of control and (9) autotelic experience (Csikszentimihalyi, 1975). Csikszentimihalyi (1990) reorganized these nine aspects of flow and categorized them into four stages according to the passage of time: prelude to flow, threshold, experience, and result.

Preceding researches and hypothetical concept models

Studies on augmented reality have been focused on technological approaches. The potential for the application of augmented reality to diverse fields such as medical science, military and entertainment is being investigated on a laboratory level. However, as augmented reality has only recently been introduced, there have been few studies to prove the effectiveness of its adoption and utilization in the field of education. Therefore, this study examines the previous research on virtual reality, which is the media that is most similar to augmented reality, as well as those on the web environment as a virtual space, and then analyzes the relationships between related factors.

Lavroff (1994) argued that Virtual Reality and augmented reality are media characterized by a strong presence based on virtuality, and that Virtual Reality has three characteristics (immersion, navigation, and manipulation) that determine presence. Immersion is not the feeling that a participant feels when observing something through a window, but is the feeling of actually experiencing a virtual world. This is, primarily, a function of hardware, as it is highly dependent upon the senses, such as sight and hearing. Navigation is a condition in which participants can freely explore and interact in a cyber world created by computing technologies. The feeling of being able to freely walk around enables participants to feel as though the world is real. Manipulation, the third factor enhancing the sense of reality created by the augmented reality system, refers to the user's ability to manipulate the virtual reality environment. Manipulation allows participants to open a virtual door, or to shoot a virtual enemy. While navigation is an interaction through which one can explore a virtual space on one’s own, manipulation is an interaction with objects as if they were in the real world, whereby participants can stimulate objects in virtual reality, such as moving, turning, and constructing them. Flauland (2002), Schubert et al. (1999), Sheridan (1992), and Slater & Wilbur (1995) have proved the influence of immersion, navigation and manipulation factors on presence through theoretical and exploratory research.

Strengthening presence in augmented reality based learning can aid an immersion in learning contents by enhancing the relationship between the learning tasks and reality. Seo Hae-rim (2003), Koh Jae-hyeok (2001), and Novak & Hoffman (1996) have proved that presence is an important factor in learning immersion. Although a large number of studies, including that of Larson (1988), have shown that presence is related to learning achievements, no research on augmented reality has been conducted.

Webster, Trevino & Ryan (1993), Massimini & Carli (1988), Novak & Hoffman (1996), Kim Young-hee, Kim Young-soo (2006), Um Myeong-yong et al. (2005), and Bricken & Byrun (1993) have proved that immersion had a positive influence on satisfaction levels through their studies on the web environment.

Larson (1998), Mayer (1978), Novak & Hoffman (1996), Kim Young-jin (2000), Baek Jae-hyeon (2006), Park Seong-ik, Kim Yeon-kyeong (2006), and Kim Hee-su (2001) showed that learning immersion had a meaningful effect on the enhancement of the understanding of learning contents.

In addition, Antonietti & Cantoia (2000), Gibson (1986), and Shim Gyuchul et al. (2003) have pointed out that encouraging learners who are utilizing Virtual Reality to conduct high-level reasoning such as analysis and synthesis had a meaningful influence on the application aspect of learning effects.

These previous studies indicate that augmented reality, as a new learning medium, can provide vivid learning experiences for learners not through abstract symbols but through the direct navigation and manipulation of three-dimensional materials. In addition, it is also expected that augmented reality can increase satisfaction levels in the understanding and application abilities of learners, by providing relevant learning contents and allowing learners to explore learning tasks.

Figure 1 shows the conceptual model of the relationship between variables, which were selected, based on theoretical background, and on the previous studies of augmented reality based learning environments that were examined above.

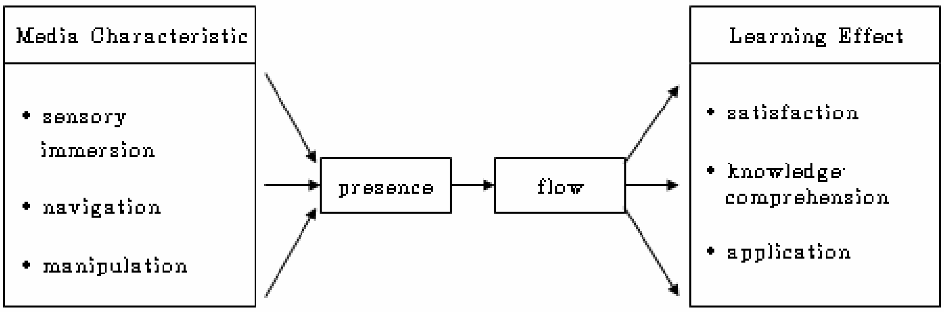

Figure 1. *Conceptual Model Drawn from Preceding Studies*

RESEARCH METHOD

This study was conducted on 290 fifth-graders at two elementary schools in Gyeonggi Province, which had similar school facilities and class environments. A total of 272 questionnaires were analyzed after excluding 4 absent students, 12 incomplete questionnaires, and 2 questionnaires that were considered to be unreliable. The program used in this study was titled, “Journey of Water”, and was jointly developed by the Korea Education & Research Information Service (KERIS) and the digital experience center of Pohang University of Science and Technology. The "Journey of Water" program was designed for fifth graders, and its contents were experiment activity type learning contents of tangible manipulation, in which students could observe and experiment with the water cycle, including evaporation, precipitation, and flowing. Contents mainly consist of the introduction to the water cycle, an experiment on the formation of clouds, an experiment on the formation of rain with condensation nucleus, and experiment on evaporation and condensation (formation of snow and rain) with controlled temperature and humidity. The contents enable learners to experience the water cycle by controlling 3D objects with a marker and tools. This program was tested and verified by experts four times, and its usability was proven in a class of 32 students in a primary school located in Gyeonggi Province.

The program based on augmented reality consisted of three sessions, in accordance with educational curriculum standards, which were the 5th sessions entitled "Fog and Clouds", the 6th session entitled "How It Rains", and the 7th session entitled "How Water Travels" of Chapter 8 Water Cycle. The program based on augmented reality was used for the experiments of each session, including an experiment on the formation of clouds, an experiment on the formation of rain with condensation nucleus, an experiment on evaporation and condensation (formation of snow and rain) with controlled temperature and humidity, and an observation on the overall water cycle. The class begins with an introduction to educational activities by an instructor, which is followed by experiments in groups, the preparation of worksheets for experiments, free group discussion, and an overview of lessons learned. This format is intended to promote learner-directed education.

I used a survey to verify flow, navigation, manipulation, presence, and satisfaction, and evaluated learning effects in terms of the learners' understanding and application in an objective manner through questions for performance evaluation. The overall reliability of the survey questions was evaluated to be 0.962, which is a very high level, and the reliability by factor ranged from 0.801 to 0.946, which was also relatively high. The structure and source of evaluation tools used in this study are as follows.

Table 1. *Evaluation Tool Structure*

Variables		Number of questions	Reference
Media Characteristics	immersion(ξ_1)	4	Lavroff, 1994
	navigation(ξ_2)	4	
	manipulation(ξ3)	4	
Presence		4	Schubert et al., 2001
Flow	clear goal	4	Jackson & Marsh, 1996
	immediate feedback	4	
	challenges-skills balance	4	
	concentration on task at hand	4	
	action-awareness merging	4	
	loss of self-consciousness	4	
	altered sense of time	4	
	sense of control	4	
	autotelic experience	4	
Learning Effect	satisfaction	4	Stein, 1997
	comprehension	5	-
	application	2	
Total		68	

The theoretical model used in this study was developed through a process of analyzing preceding studies, developing measuring tools, holding augmented reality based classes, conducting survey and achievement evaluations, and confirming a final model through the analysis of confirmatory factors and structural equation modeling. All the data obtained from the survey and achievement evaluation was processed using SPSS 12.0 for Windows, and AMOS 5.0 was used to verify a hypothetical model.

RESEARCH RESULT

Confirmatory Factor Analysis (CFA) is a way to confirm a hypothesis model when researchers have knowledge regarding variables and factors (concepts) and their theoretical background. This study used Maximum and Likelihood (ML), which supposes multivariate normality for confirmatory factor analysis, and evaluated fitness to check the optimum state of the structure concept and variable configuration. The fit indexes and standards that were utilized for the result model were GFI (Goodness-of-Fit Index: over 0.9), AGFI (Adjusted Goodness-of-Fit Index: over 0.9), TLI (Tucker-Lewis Index: over 0.9), CFI (Comparative Fit Index: over 0.9), and RMSEA (Root Mean Square Error of Approximation: below 0.05).

According to the first confirmatory factor analysis, most indexes exceeded the recommended standard (χ2=718.340, *df*=362, GFI=0.847, AGFI=0.816, TLI=0.904, CFI=0.914, RMSEA=0.060), showing that the overall fitness of the model was high. However, the GFI, AGFI, and RMSEA indexes fell short of the standard. Therefore, to exclude variables whose factor loading was less than 0.5 from the analysis, the following factors were excluded, one by one, from the first measurement equation: NA1 from among the navigation factors, IM2 from among the sensory immersion factors, MA1 from among the manipulation factors, PR3 from among the presence factors, FL4 (specific feedback), FL7 (loss of self-consciousness), FL8 (loss of concept of time), and FL9 (self-purposive experience). After the measurement equation was modified in this manner, the fit index of this equation changed to $\chi 2$=268.847, *df*=174, GFI=0.916, AGFI=0.900, TLI=0.962, CFI=0.968, RMSEA=0.045, an equation fitness superior to the first one, with improved indexes, including GFI and AGFI.

To verify the overall structure of the research model, the fitness of the model was analyzed with $\chi 2$ verification and fit index, as in the confirmatory factor analysis, and a significant result of $\chi 2$=318.086, *df*=217 was produced. According to the fit index evaluation result, the fit index was proved to be satisfactory with GFI=0.909 (recommended level is above 0.9), AGFI=0.885 (recommended level is above 0.9), TLI=0.963 (recommended level is above 0.9), CFI=0.968 (recommended level is above 0.9), RMSEA=0.041 (below 0.05 is good fitness, below 0.08 is reasonable fitness, below 0.1 is ordinary fitness). To improve the values of AGFI and NFI, which were somewhat lower than the recommended level, we explored an optimum model through the addition of free parameters. The results of this exploration showed that the modification index of "manipulation→satisfaction" was 24.479 and that of "manipulation→application" was 11.419, both of which exceeded 10, a conservative standard, proving that there is room for modification in this model. Therefore, through the investigation of the theoretical background which could support these results, the routes that showed the direct effect of "manipulation-→satisfaction" and "manipulation→application" were added. The final model modified in this manner can be seen in Figure 2.

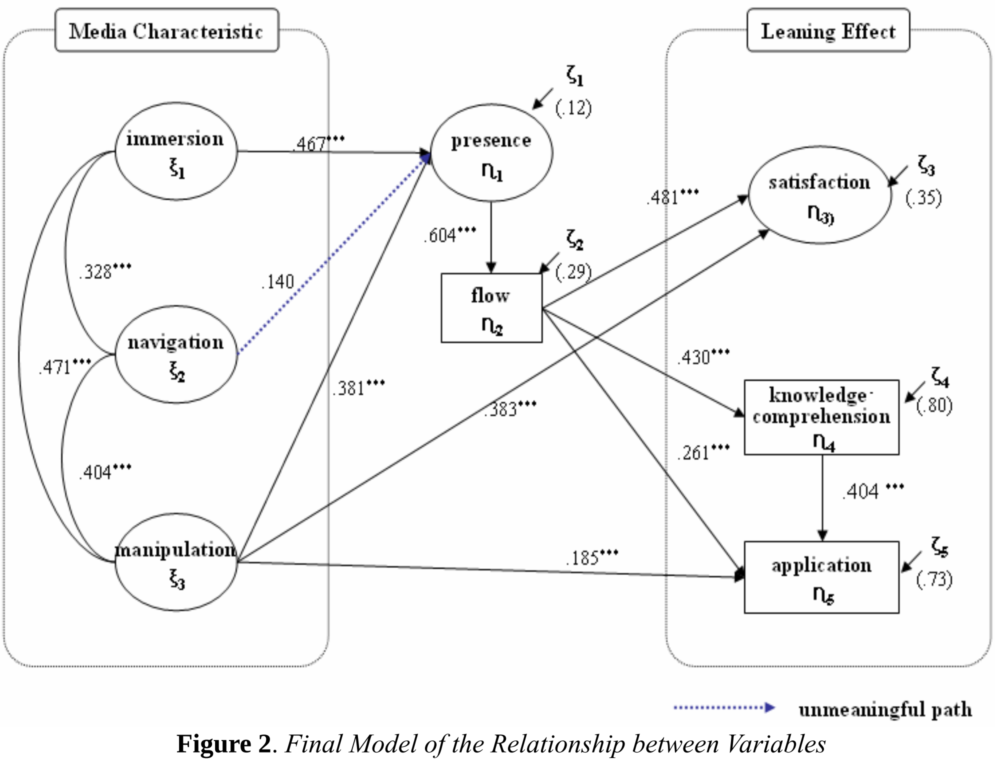

Figure 2. *Final Model of the Relationship between Variables*

As seen in Figure 2, of the total of eight hypothetical routes established at the beginning of the research, seven routes proved to be meaningful at the .001 level of significance, and one hypothetical route of manipulation->presence was proved not to have a meaningful influence at the .05 level of significance. In addition, new hypothetical routes (manipulation→satisfaction, manipulation→application) were added at the .001 and the .01 level of significance, respectively. Based on this final model, for an analysis of the media utilization effectiveness model in an augmented reality based learning environment, the regression coefficient, standard error, and *t*-value were measured. As seen in Table 2, the results found no large standard error exceeding 2.5 that could cause problems when distinguishing models.

Table 2. *Effect Analysis Result of Relations between Factors*

Path			Estimates	S.E	*t*	
1. immersion(ξ_1)	→	presence(η_1)	0.532	0.136	3.914^{***}	
2. navigation(ξ_2)	→	presence(η_1)	0.160	0.107	1.490	
3. manipulation(ξ_3)	→	presence(η_1)	0.308	0.074	4.162^{***}	
4. presence(η_1)	→	flow(η_2)	0.505	0.063	7.979^{***}	
5. flow(η_2)	→	satisfaction(η_3)	0.604	0.087	6.948^{***}	
6. flow(η_2)	→	comprehension(η_4)	0.623	0.087	7.148^{***}	
7. flow(η_2)	→	application(η_5)	0.434	0.103	4.200^{***}	
8. comprehension(η_4)	→	application(η_5)	0.462	0.059	7.807^{***}	
9. manipulation(ξ_3)	→	application(η_5)	0.326	0.058	5.601^{***}	new
10.manipulation(ξ_3)	→	application(η_5)	0.207	0.065	3.170^{**}	new

$^{**}p$ <.01, $^{***}p$ <.001

The direct and indirect effects as well as the total effects among media characteristics, presence, flow, and educational effectiveness factors in augmented reality based learning are presented in the following Table 3, and its results are as follows:

Table 3. *Effects of Related Variables in Augmented Reality Based Learning*

Product Variables	Predicting Variables	Effects			Total Explanatory Power
		Direct effects	Indirect effects	Total Effects	
presence (η_1)	immersion(ξ_1)	0.467		0.467	0.762
	navigation(ξ_2)	0.140		0.140	
	manipulation(ξ3)	0.381		0.381	
flow (η_2)	immersion(ξ_1)		0.282	0.282	0.365
	navigation(ξ_2)		0.085	0.085	
	manipulation(ξ_3)		0.230	0.230	
	presence(η_1)	0.604		0.604	
satisfaction (η_3)	immersion(ξ_1)		0.136	0.136	0.549
	navigation(ξ_2)		0.041	0.041	
	manipulation(ξ_3)	0.383	0.111	0.494	
	presence(η_1)		0.291	0.291	
	flow(η_2)	0.481		0.481	
comprehension (η_4)	immersion(ξ_1)		0.121	0.121	0.185
	navigation(ξ_2)		0.036	0.036	
	manipulation(ξ_3)		0.099	0.099	
	presence(η_1)		0.260	0.260	
	flow(η_2)	0.430		0.430	
application (η_5)	immersion(ξ_1)		0.123	0.123	0.431
	navigation(ξ_2)		0.037	0.037	
	manipulation(ξ_3)	0.185	0.100	0.285	
	presence(η_1)		0.263	0.263	
	flow(η_2)	0.261	0.174	0.435	
	comprehension(η_4)	0.404		0.404	

$^{**}p$ <.01, $^{***}p$ <.001

First, in this model, media characteristic factors (sensory immersion, navigation, manipulation) were proven to have the greatest influence on presence, explaining 76.2% of its variables. Among the media characteristics, sensory immersion in particular was proven to have a direct effect of 0.467 and a manipulation of 0.381, indicating that sensory immersion and manipulation make a great contribution to the prediction of presence. This result supports the theory of Slater and Wilbur (1995) examined in previous studies, as well as that of Lavroff (1994), which stated that sensory immersion and manipulation had an impact on presence. This also supports the case studies on virtual environments by Fauland (2002), which showed that the higher the sensory immersion perceived by learners, the higher the level of presence in augmented reality based learning. On the other hand, the path coefficient of navigation was 0.140 and did not prove to make a statistically meaningful contribution to the overall improvement of explanation capabilities at the 0.05 level of significance.

Second, media characteristic factors (sensory immersion, navigation, and manipulation), independent variables, and presence, which are also a parameter, explain 36.5% of all variables of flow. In particular, presence had a significant relationship to flow, showing a great effect of 0.604 on the factors' relative importance and contribution. This supports the research results of Goh Jae-hyeok (2001) and Seo Hae-rim (2003), which were discussed earlier. In addition, sensory immersion and manipulation proved to have a significant impact on flow, using presence as a parameter. It was proved that navigation did not make a statistically significant contribution to the overall improvement of explanation capabilities.

Third, media characteristic factors (sensory immersion, navigation, and manipulation), independent variables, and the parameters of presence and flow explained 54.9% of all variables of satisfaction. First of all, flow had a high effect of 0.481 on the level of satisfaction, which is in line with the results of other exploratory studies by Novak and Hoffman (1996), Massimini and Carli (1988), Um Myeong-yong, et al. (2005) and Kim Young-hee and Kim Young-soo (2006), which were conducted online, and also proves that the higher the flow, the higher the level of satisfaction in the augmented reality based learning environment will be. Also, sensory immersion, manipulation, and presence were all proven to be important factors in predicting satisfaction. Their relative importance and contribution were: manipulation 0.383, presence 0.291, and sensory immersion 0.136. In particular, manipulation, whose importance was not predicted by the existing hypothetical model, was shown to have a significant influence of 0.494 on the satisfaction level, which reveals that strengthening manipulation through the tangible interface of the augmented reality media contributes strongly to the level of satisfaction.

Fourth, media characteristic factors (sensory immersion, navigation and manipulation), independent variables, and the parameters of presence and flow explained 18.5% of all variables in the knowledge and understanding aspects of learning effects. First, flow showed a high level of prediction capability, with a high degree of influence of 0.430 on the learning effect of knowledge and understanding. This result supports the previously discussed theories of Mayers (1978), Csikszentmihalyi & Larson (1993), and is consistent with the results of exploratory research by Kim Young-jin (2000) and Park Sung-ik and Kim Yeon-kyung (2006), showing that the more learners are absorbed in learning, the higher their learning effect in the aspects of knowledge and understanding. Apart from flow, presence showed a relative importance and contribution of 0.260 and immersion a contribution of 0.121, as factors significantly explaining learning effects in the aspects of knowledge and understanding, while navigation and manipulation did not have significant prediction capabilities.

Fifth, media characteristic factors (sensory immersion, navigation and manipulation), independent variables, and the parameters of presence and flow explained 43.1% of all variables in the application aspect of learning effect. First of all, flow had a large effect of 0.435 in the application aspect of learning effect. This result is in line with the previously discussed structure model of Novak and Hoffman (1996), even though their research was about the online environment, showing that the more learners are absorbed in learning, the higher their achievement in terms of application. Also, the learning effect in terms of knowledge and understanding had a direct effect of 0.404 on the learning effect of application, proving that the higher the level of achievement in terms of knowledge and understanding in augmented reality based learning, the higher the achievement in terms of application.

In addition, sensory immersion, manipulation and presence provided meaningful explanations of the learning effect in terms of application, while navigation did not prove to make a statistically significant contribution to the overall improvement of explanation capabilities. In terms of the relative importance and contribution level of factors, flow was 0.435, followed by knowledge & understanding at 0.404, manipulation at 0.285, presence at 0.263, and sensory immersion at 0.123. In particular, manipulation, whose effect was not predicted by the existing hypothetical model, was shown to have a medium-level influence of 0.185 in application, demonstrating that the methods of augmented reality's tangible interface manipulation made a contribution to the effects of application as well as on the satisfaction level of learning.

This research proves that sensory immersion and manipulation, as media characteristic factors, are important factors in determining presence and flow, and that these media characteristic factors are factors determining the learning effect in terms of satisfaction, knowledge & understanding, and application. It also indicates that effective design of three-dimensional objects and the strengthening of manipulation through tangible interfaces are the most essential factors when designing augmented reality based learning media.

CONCLUSIONS AND SUGGESTIONS

Whenever a new medium is introduced to education, people are always curious about whether it is better than existing teaching methods. As studies on this topic are continuously being conducted with the emergence of each new media, the same questions are being posed for this advanced media (Na Ilju, 1995). These studies about media can be classified into two categories: efforts to determine a comparative advantage of the media, and efforts to investigate the unique capabilities of a given medium. This study aimed to discover the distinct characteristics and effectiveness of augmented reality as an emerging learning and teaching medium.

This study examined media characteristic factors, the unique features of augmented reality, and the causal relationship between these factors and learning effects. It also aimed to prove the effectiveness of the application of augmented reality technology as a new technology in the education field.

With the exception of navigation, the research showed that all factors, including immersion, manipulation, presence, and flow proved to have a meaningful influence on learning effects such as satisfaction, knowledge & understanding, and transfer. The manipulation factor, whose effect was not predicted in the first theoretical model, was shown to have not only an indirect but also a direct effect on satisfaction and the application aspect of the learning effect.

In particular, of the factors that were focused on when the research variables were selected, firstly, sensory immersion was proven to have a meaningful influence on the knowledge & understanding and the application aspects of cognitive learning effect, using presence and flow as parameters. This result showed that the application of augmented reality technology makes a meaningful contribution to the absorption in and the effectiveness of learning, in addition to providing sensory enjoyment. Secondly, in terms of the learning effect, the application of augmented reality media had a greater influence on the application factor (43.1%) than on the knowledge & understanding factor (18.5%). This result shows that the application of augmented reality media had a meaningful effect in actual context, going beyond the acquisition of non-contextualized knowledge focused on the understanding of existing concepts. It also confirms the research results of Kim Hoe-su (1999) that the application of augmented reality techniques contributes to the improvement of scientific analysis and general capabilities, as well as the prediction that augmented reality will have an effect not only on the acquisition and understanding of simple concepts but also on their application, by raising situational awareness (Azuma, 1997; New Media Consortium and Educause Learning Initiative, 2006; Romero, Santiago, & Correia, 2004).

Also, the manipulation factor through the use of a tangible interface discussed earlier, which is one of the distinct characteristics of augmented reality, proved to have not only an indirect but also a direct effect on the satisfaction and application aspects of the learning effect. This is assumed to be the result of a good combination of the experience activity type of augmented reality contents, which was used in this study, with the manipulation method of the augmented reality media through the utilization of a tangible interface. This result supports the research of Shelton (2003), which argues that learners can increase their achievements and satisfaction in learning by enhancing their sense of control through the manipulation of learning contents, as well as that of Billinghurst (2003), who found that the interaction with augmented reality contents through the use of a tangible interface will enable an active learning process and increase the application capability of knowledge.

On the other hand, in this study, navigation was proven to not have a significant influence on flow, which runs counter to the commonly discussed research results on immersive Virtual Reality. This result is assumed to show a difference in the media characteristics of augmented reality from those of the immersive Virtual Reality. Learning contents, in an immersive Virtual Reality, are generally processed into artificial objects according to the attributes of tools, wherein the navigation factor based on the curiosity about a new virtual world made up of artificial objects is assumed to have a major effect on presence. On the other hand, it is also assumed that, in an augmented reality in which the real world is combined with virtuality, sensory immersion and manipulation, rather than navigation enabling exploration into the unknown world, had a greater influence on learners because of its learning experiences, in which people can manipulate virtual objects in a real world. However, as the results of this study are based on the application of tangible activity type augmented reality in fixed locations, the relationship between factors may vary if the conditions of augmented reality based learning activities change, for example, to mobile-based augmented reality.

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