Applying Augmented Reality to E-Learning for Foreign Language Study and its Evaluation

Tadashi Miyosawa[1], Mayuko Akahane[1], Kentaro Hara[1], Kikunori Shinohara[2]

[1]Department of Business Administration and Information, Tokyo University of Science, Suwa, Nagano, Japan

[2]Center of General Education and Humanities, Tokyo University of Science, Suwa, Nagano, Japan

Abstract - *Various studies have been undertaken to adapt Augmented Reality (AR) technology for use in education. We see AR as being suitable for creating an enjoyable learning experience (edutainment) for students. In this study, we developed an AR application based on the same content as conventional printed teaching material focusing on the field of foreign language study. The learning efficacy of the two media was assessed by comparing verification test results and monitoring brain activity during the learning process. The results show that there is no significant difference in test results between the two media. However, we found that the subjects' brains were more active while studying the printed teaching materials than the AR teaching materials. We believe this shows that the proposed method of study is overall a more natural one and, when compared with traditional methods of study, has the potential to be less stressful for students.*

Keywords: Augmented reality (AR), E-Learning, Edutainment, Brain Activity, NIRStation

1 Introduction

1.1 Background

Augmented reality, commonly referred to as AR, has garnered significant attention in recent years. This terminology has been used to describe the technology behind the expansion or intensification of the real world. To "augment reality" is to "intensify" or "expand" reality itself [1]. Specifically, AR is the ability to superimpose digital media on the real world through the screen of a device such as a personal computer or a smart phone, to create and show us a world full of information that we could never have been able to conceptualize until now.

There are various types of AR, generally divided into the following broad categories [2]. First, there is the marker type—using a camera connected to a device, and once a "marker" comes into view, the digital image data are superimposed onto the display. In contrast to this, there is the marker-less type—the subject of the image taken from the camera itself has its particular shapes and colors analyzed and the digital image data are superimposed based on these shapes and colors. Both kinds of AR use what is called, image recognition technology. Moreover, location information AR, utilizes a GPS and other sensors installed on smart phones to gather location data and superimpose digital information relating to that particular location. This variation in AR technology is commonly known through the popular Japanese smart phone application, Sekai Camera [2]. Sekai Camera enables users to view the scenery, superimpose information about the subject of the scenery (such as information about a store) onto the image using the "Air Tag" feature, and upload it for other users to view.

Using AR technology, we are able to bring concepts that have only existed in fantastical worlds, such as those in Manga and Anime, to the real world; the ability to enrich our world further with, "interesting," and "fun" aspects excites us. As Kobayashi [3] noted, "There is no reason that media such as television and movies, as well as Manga and video games, cannot be used for just entertainment. Of course, the enjoyment gained from these media is the fundamental component; that component can be taken to create an 'enjoyable learning experience,' in other words, 'Edutainment' [4]. With that in mind, even as a new medium, AR is suited for this as well." We also believe in the promotion of the concept of creating an enjoyable learning experience for students utilizing AR technology and used this as the basis of our research.

1.2 Previous Research

Various studies have been undertaken to adapt AR technology for use in education.

In Chang's study [5], the authors used AR technology to implement an AR learning system for learning English vocabulary. The results of this study show that system quality is a critical factor affecting perceived satisfaction, perceived usefulness, and AR learning effectiveness.

You [6] demonstrated a new e-learning/e-business experience using mobile AR. This system employs advanced image processing and search technologies that allow users to capture designated images such as product advertisements and quickly match them to the vendor's database to obtain detailed product information associated with the images. The same is possible in an e-learning environment.

Kondo's research [7] showed that AR is advantageous in expanding the functionalities of the traditional education textbook. This was demonstrated with educational material developed to explain the structure of the human brain using 3DCG (computer generated 3D technology) and sound technology. In addition, educational material was developed to help students learn about mathematical shapes, and this was used in high school classes, followed by a questionnaire to measure the success of the experiment. According to the results of the questionnaire, 70% of the students were of the opinion that the AR teaching material was helpful in understanding the subject matter.

In the research by Teshima et al. [8], the team developed their own teaching materials using 3DCG and AR technologies for use in children's geography classes and provided proof that these were successful in enhancing the learning experience for the students. As a result of the AR teaching experience, students achieved higher scores in naming regions and identifying their locations. From these results, Teshima et al. showed that AR technology is an important element in geography education, particularly for the recall of geographical names and locations by students.

However, to date, there have been no studies showing for which subjects AR-based learning aids are specifically effective, or whether AR is even a valid learning aid for any subject, thus leaving this open to discussion.

1.3 Aim of Study

The aim of this study is to assess whether AR teaching materials are useful in learning foreign languages. For this experiment, we developed an AR application for learning purposes using the same content as selected conventional print media teaching material. The learning efficacy of the two media was assessed by comparing verification test results and monitoring brain activity during the learning process. Based on the results, this study not only shows the suitability of having AR-enabled teaching materials in a foreign language learning environment, but it also considers the benefits of using this technology across other fields of study.

1.4 Structure of the Paper

Section 1 provides background information, previous research related to the subject matter, current issues, and the purpose of this study. Section 2 introduces the development environment, the materials used for AR development and the verification tests based on the content of the foreign language teaching materials. Section 3 introduces the two experiments based on the teaching materials developed in the previous section. Section 4 presents the results of the experiments carried out and provides an analysis thereof. Section 5 discusses the future potential of AR technology as a teaching aid based on the results. Section 6 provides a summary of the paper.

2 Creation of Teaching Materials

2.1 Development Environment

2.1.1 ARToolKit

ARToolKit is a C/C++ Library Package used to implement AR applications using AR marker technology. The example application shown in Fig. 1 overlays a 3DCG image on top of a marker detected by the Web camera. The marker and the 3DCG images can be developed by the user.

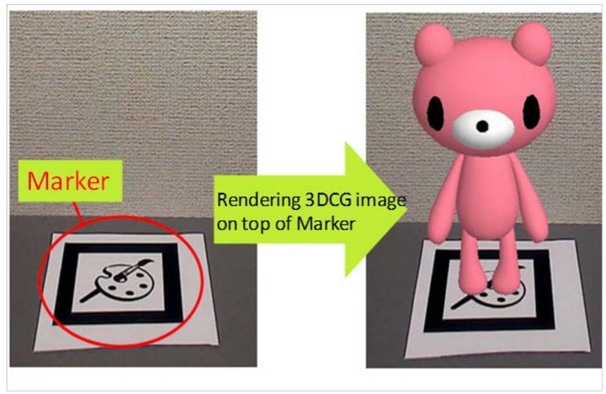


Fig. 1 Example of an application created using the ARToolKit

In this study, the ARToolKit was used to create the teaching material application. Table 1 gives details of the application environment.

Table 1 Application environment used in this research

NoteBook PC		WEB Camera	
Product	Fujitsu FMV-E8290	Product	Logicool 2.0-MP Webcam C600
CPU	Intel(R) Core(TM)2 Duo CPU P8700(2.53GHz)	Capture capability	2 Mega pixels (Max1600×1200)
Memory	2GByte	Frame rate	Maximum 30fps
OS	Windows 7 Professional		

2.1.2 Metasequoia

Metasequoia is 3D Object Modeling software that can be used to edit 3D objects. For this study, we created two scenarios for use as teaching material using the freeware version of Metasequoia (Figs. 2 and 3).

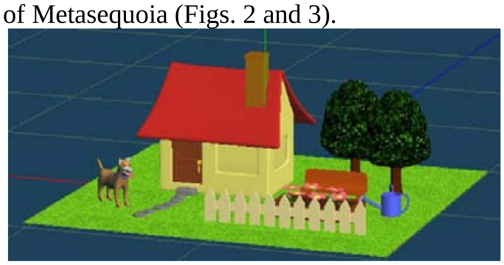


Fig. 2 Teaching Material 3DCG（A）

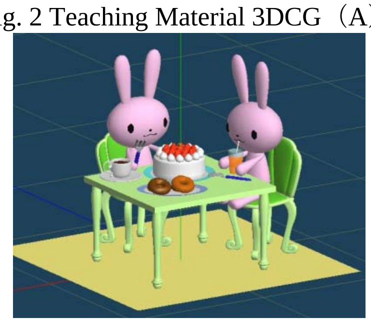


Fig. 3 Teaching Material 3DCG（B）

2.2 Application of Augmented Reality

In this study, teaching material applications for the study of foreign languages were developed using AR technology. The teaching materials were picture-based, but instead of using illustrations, 3DCG images were projected with the expectation that this would have a significant impact on the student's overall learning experience.

2.3 Deciding which Foreign Language to use

For this study, Indonesian was chosen as the foreign language, because for the best results in the experiment, it was necessary that the subjects were taught a foreign language in which they had had no prior tuition. In addition, non-alphabet languages such as Chinese and Greek were excluded, since it was felt that the difficulty of learning a different character set would interfere with the assessment of the teaching materials. Having taken the above factors into consideration, we decided that Indonesian was the most suitable foreign language for the purposes of this study.

2.4 Development of Teaching Materials

In this study, an adaption of AR for use in learning a foreign language (hereafter referred to as AR Material) and conventional print media (hereafter referred to as Printed Material) were created for comparing the learning efficacies of the two different media. In addition, since each subject would see both the AR and Printed Materials, two sets of teaching materials (A and B) were created in each media to avoid any overlap in content.

In the AR Material, a Web camera was connected to a notebook PC and the 3DCG image of the teaching material was overlaid onto the marker (Fig. 4) with the vocabulary boxes containing both the Japanese and Indonesian words. The execution process is shown in Fig. 5.

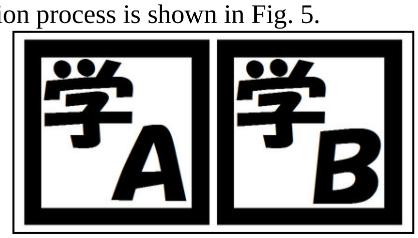


Fig. 4 Markers used in the AR teaching material application (Left: marker A, Right: marker B)

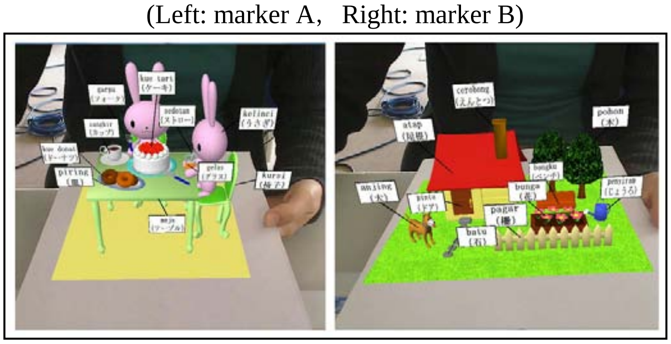


Fig. 5 Execution process of the AR teaching material (Left: teaching scenario A, Right: teaching scenario B)

For the Printed Material, the 3DCG images used in the AR Materials were rendered and printed; the vocabulary boxes were used in the same way as in the AR Material.

2.5 Verification Test

For the experiment, a verification test was created based on the materials introduced in Section 2.4. Questions are presented in Japanese; the subject then selects the Indonesian word from a group of words on the question paper and writes the answer in the corresponding answer field.

3 Experiments

3.1 Experiment 1 - Verification of the Efficacy using the Confirmation Test

3.1.1 Aim

The efficacy of the AR Teaching Materials was assessed using the results of the verification test following the study phase of this experiment. In addition, questionnaires seeking the thoughts and opinions of the subjects on their experiences in the experiment were also used in the evaluation.

3.1.2 Subjects

Thirty students from the Tokyo University of Science, Suwa, and Nihon University participated as subjects in this experiment.

3.1.3 Materials

・Four sets of teaching materials (AR Materials A and B, and Printed Materials A and B)
・Web camera with a notebook PC
・Two different verification tests (Tests A and B)
・Questionnaire
・Clock for measuring time
・Stationery for writing

3.1.4 Method

For each set of teaching material, a 2-min period was given in which to study the materials and another 2-min period was given to complete the subsequent verification test. However, a further 30-s initial allowance was given for the subjects to familiarize themselves with the AR Material. During this time, the words were not displayed in the vocabulary boxes. Furthermore, in order to prevent any bias in the implementation data, the teaching material for each subject included a set of rules, which the subject had to follow during the study phase. After completing both verification tests, the subject then completed the questionnaire.

3.1.5 Process

The experiment was carried out using the process described below.

First, the Web camera was connected to the notebook PC and the AR application started. This was done to ensure that the teaching materials were instantly accessible by the subject. The subjects were called one by one and asked to carry out the activities detailed in Section 3.1.4 in the order given below.

For the AR Teaching Materials

1. Summary and explanation of the teaching materials to the subject.
2. The examiner gives the marker to the subject.
3. Practice session with the AR application for 30 s.
4. Study phase with the AR application for 2 min.
5. Terminate the AR application and return the marker to the examiner.
6. Subject completes the verification test within a 2-min period.
7. Subject returns the verification test paper and writing implements.

For Printed Teaching Materials

1. Summary and explanation of the teaching materials to the subject.
2. The examiner hands over the teaching materials. Study phase with the Printed Material for 2 min.
3. The teaching materials are returned to the examiner.
4. Subject carries out the verification test within a 2 min period.
5. Subject returns the verification test paper and writing implements.

3.2 Experiment 2 – Monitoring Brain Activity during the Study Phase

3.2.1 Aim

The efficacy of each set of teaching material was assessed by monitoring the brain activity of the subject during the study phase of this experiment. The aim was to determine whether there was any significant difference in the subject's brain activity during the study phase with each set of teaching material.

3.2.2 Subjects

Ten students from the Tokyo University of Science, Suwa, participated as subjects in this experiment.

3.2.3 Materials

・Four sets of teaching materials (AR Applications A and B and Printed Materials A and B)

・Web camera connected to a notebook PC

・Brain activity monitoring device (NIRStation: multi-channel near-infrared (NIR) spectroscopic brainwave measuring device)

Details about the NIRStation:

NIR light passes through fiber-optic sensors placed on the scalp, allowing the device to display fluctuations in the blood flow through the cerebrum on the monitor (Fig. 6). In active regions of the brain, there is an increased rate of blood flow (hereafter referred to as hemoglobin levels (oxy-Hb). Approximately 25-30 mm below the scalp, NIR wavelengths disperse and are absorbed repeatedly until they weaken and return to the scalp. During the monitoring period, the rate of change in blood flow can be calculated using the detected absorption rate of oxy-Hb and optical path length (Fig. 7). The subject wears a headset with NIR-detecting plots attached to it during the monitoring process (Fig. 8).

Fig. 6 NIRStation (source: Shimadzu Corporation home page)

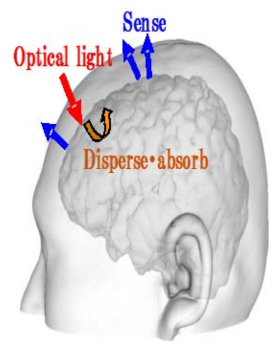


Fig. 7 NIRStation measurement method

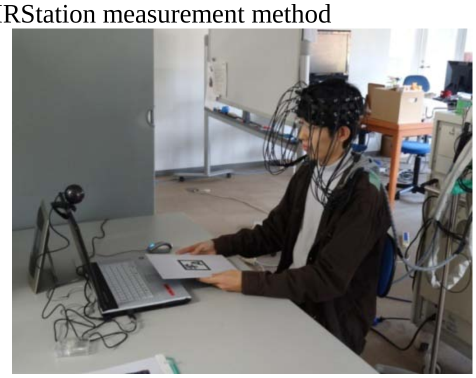


Fig. 8 Monitoring a subject

3.2.4 Method

Subjects were given 2 min to study each set of teaching material, during which time their brain activity was monitored. They were given a 10-s rest period before and after each study session and were instructed not to say or think about anything so as to completely rest their brains. This was done in order to derive the difference in brain activity between the rest period and study session and further to avoid any bias in the data. Each subject rigidly followed the procedure set out for them. As the aim of the experiment was to measure the subject's brain activity during each study session, the verification test results were not taken into consideration for this experiment. However, as this could have affected the subjects' attitude toward the study session and, therefore, the results of the experiment, this was not disclosed to the subjects.

3.2.5 Process

The experiment was carried out using the process described below.

First, the Web camera was connected to the notebook PC and the AR application started. The brain activity monitoring device was also prepared so that subjects could be tested in a timely manner. The subjects were called one by one and were asked to carry out the activities in the given order.

For AR Teaching Materials

1. Summary and explanation of the teaching materials and method to the subject and an explanation of the monitoring device.
2. The headset is placed on the subject's head and its functionality tested.
3. The marker is given to the subject and the monitoring period begins.
4. The AR teaching material application is started.
5. Ten-second rest period → 2 min study period →10 s rest period
6. The monitoring period ends, the AR application is terminated, and the marker is returned to the examiner.

For Printed Teaching Materials

1. Same as for AR Material.
2. Same as for AR Material.
3. The Printed Materials are given to the subject and the monitoring process begins.
4. Ten-second rest period → 2 min study period →10 s rest period
5. The monitoring period ends and the teaching materials are returned to the examiner.

The experiment ends once all activities have been carried out twice and the helmet has been returned to the examiner.

4 Results and Analysis

4.1 Results and Analysis of Experiment 1

First, a t-test was carried out to ascertain whether there was a significant difference between the verification test results for each set of teaching material.

Table 2 T-test results based on the verification test

	AR	Printed Material
Mean	6.533	6.567
Variance	5.361	3.840
Observations	30.000	30.000
Correlation coefficient	0.357	
Hypothesized mean difference	0.000	
df	29.000	
t	-0.075	
P(T<=t) one-tail	0.470	
t Critical One-tail	1.699	
P(T<=t) Two-tail	0.941	
t Critical Two-tail	2.045	

As shown in Table 2, the calculated P value is above the critical threshold of 0.05, showing that no significant difference exists between the efficacies of the different teaching materials.

Next, the results of the questionnaire following the use of the teaching materials were aggregated into five focus areas. The averages for each area were compared in a radar chart.

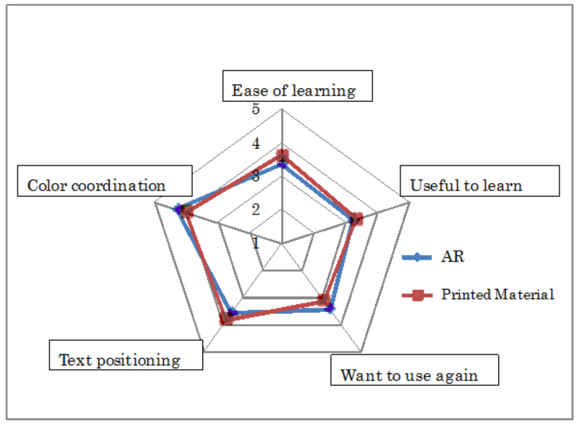


Fig. 9 The mean value for each area

It can be understood from Fig. 9 that the AR Teaching Materials and the Printed Teaching Materials generally have similar results. Because of this, a t-test was carried out to ascertain any differences within the areas; the only significant difference observed was the difference in "Ease of Learning" between the two sets of teaching materials.

A P value below the critical threshold of 0.05 was obtained, showing that subjects found it easier to learn from the Printed Materials than from the AR Materials.

In addition, the subjects were asked to give their opinions as to the positive and negative points of each set of teaching material. Common opinions were summarized and the number of people giving that opinion was recorded.

Table 3 Positive and negative points of the two sets of teaching materials

	Positive Comments	Subjects	Negative Comments	Subjects
Printed Material	Just like I have always studied	13	Boring	3
	Easy to see	4	Hard to memorize word	3
	Illustration is easy to understand	3	Feel that something is missing	2
	Many way to use	2		
AR	Flesh stimulus	9	Vocabulary is hard to see	9
	Visualized in 3D	7	Hard to concentrate to learn	5
	Easy to memorize word	4	Operation is little bit hard	2
	It is fun and interesting	3	Tired eyes	2
	Rabbit is cute	3		
	Feel future possibility	3		
	Easy to cope with	2		

(Note: Only opinions shared by two or more people are listed.)

As seen in Table 3, the most prevalent positive point about the Printed Material was that it was, "Just like I have always studied," with almost half the subjects agreeing. This opinion was drawn from the fact that the subjects were familiar with studying using printed media prior to this experiment and therefore found it easier to use. Based on this observation, it is clear why the subjects rated the Printed Teaching Material higher in the "Ease of learning" category; the subjects had no prior experience with the AR Teaching Material and were so accustomed to the use of print media that this strongly influenced how they felt.

To summarize the comparative opinions of other subjects, many shared the opinion that the AR Teaching Material was a "fresh stimulus," and that the major positive difference was that it was "visualized in 3D." As for the negative points, the subjects commented that the "vocabulary is hard to see [in the vocabulary boxes]," and also that "it was hard to study."

4.2 Results and Analysis of Experiment 2

To ascertain the differences in the subject's brain activity when studying the different sets of teaching materials (AR and Printed), the rate of oxygenation (Hemoglobin/oxy-Hb) in the subject's brain was monitored.

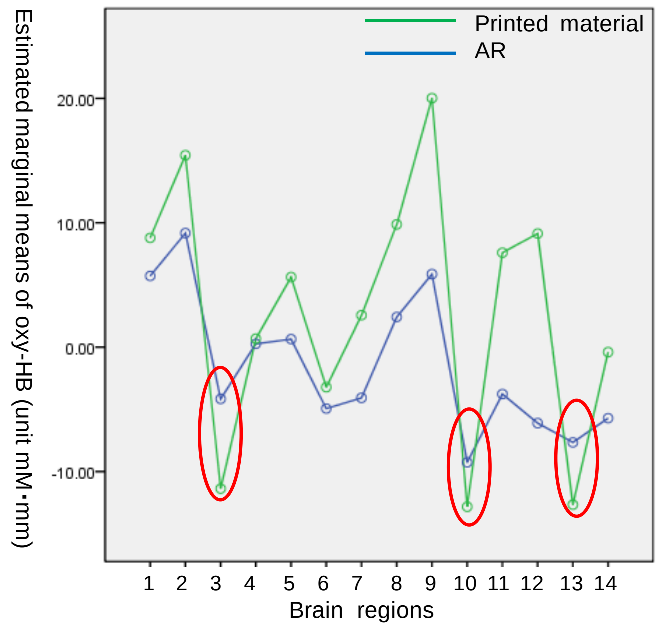
Table 4 Results of variance in amount of oxy-Hb for each set of teaching material (UNIANOVA)

Source	TypeIII Sun of Sequences	df	Mean Square	F	Sig. (p)
Intercept	309.882	1	309.882	1.790	.181
A subject testee	23276.812	9	2586.312	14.939	.000
Learning Method(LM)	3645.227	1	3645.227	21.055	.000
Brain area	44794.318	13	3445.717	19.903	.000
LM * Brain area	9433.124	13	725.625	4.191	.000
Error	145944.601	843	173.125		
Total	226152.584	880			
Corrected Total	226098.227	879			

From Table 4, it can be seen that there is a significant difference in brain activity when using the AR Teaching Materials and the Printed Teaching Materials, since the significance probability (p value) of 0.000 is well below the critical threshold of 0.05. The brain activity observed during the study sessions with the Printed Materials can be understood as overall stimulation.

Following this, the results of the t-test carried out to show the estimated average rate of oxygenation in the brain regions are shown in Fig. 10. In most of the regions, the Printed Teaching Material activates the brain more than the AR Teaching Material. However, the AR Teaching Material activated (3) the left angular gyrus, (10) the right angular gyrus, and (13) the right superior parietal association cortex as shown in Fig. 10.

In particular, the parietal association cortex exists to gather visual, somatic sensation, and hearing information and, based on this, co-ordinate the visual focus, hearing, sense of balance, and other sensations. The parietal association cortex then integrates all this information together. In other words, it can be said that the parietal association cortex is there to integrate the absolute, real space (Newton space) with the sense of self-awareness (sensation space) [12].



1.Left dorsolateral prefrontal cortex,2.left inferior frontal gyrus,3.left angular gyrus,4.left superior frontal gyrus,5.left frontotemporal region,6.left superior parietal association cortex,7.left motor cortex,8.right dorsolateral prefrontal cortex,9.right inferior frontal gyrus,10.right angular gyrus,11.right superior frontal gyrus,12.right frontotemporal region,13.right superior parietal association cortex,14.right motor cortex

Fig. 10 Estimated marginal means of oxy-Hb for each region of the brain

We believe that the parietal lobe area was activated by the sight of the 3DCG image being overlaid on the marker. When using the AR Teaching Material, the illustrations from the Printed Teaching Material appeared as 3DCG images and had a 3D effect on the eye. If the subject turned the marker, the 3DCG image would also turn in the same manner, allowing the subject to view the 3D image in whatever way he/she preferred. As a result, we hypothesize that there was a tendency for the subjects to experience 3DCG as an inclusive or surreal experience as the 3D effect made the imagery more believable. This sensation is indeed understandable as it is a characteristic of AR to "extend and expand reality as we know it," and we believe that this is a prime example of the characteristic.

In addition, the angular gyrus acts as the center of various sensory receptors such as vision and hearing and, as such, can be thought of as being primarily responsible for storing vocabulary, understanding, and verbalizing this when it comes to languages. If this area were to be compromised, the ability to read and write would also be compromised; a person with a damaged angular gyrus would not be able to understand a metaphor, for example [14].

Following on from this, it was found that when it came to the frontal lobe the Printed Teaching Materials had a stronger effect in activating the frontal lobe. The frontal association cortex plays a key role in the brain's thought, planning, conceptual thinking, and judgment. In order for these to perform, as Baddeley [15] pointed out, "working memory" needs to be accessed while these thoughts are being processed [13]. In other words, when studying a foreign language the brain acquires and stores new words and needs to frequently access the working memory, thereby creating much activity, which we detected.

To summarize the above, the subjects who used the AR Teaching Materials to study did not experience significant brain activity. Their sense of reality was synthesized with the virtual world via the PC monitor and the 3D imagery interacted with their own co-ordinate space. We believe this allowed the brain to associate the foreign words with the imagery, allowing it to acquire and store words more naturally.

We observed in Experiment 1 that there was no difference in learning efficacy between using the AR Teaching Materials and the Printed Teaching Materials. This shows that, when taking into account the fact that the AR Teaching Materials were compared with a pre-existing method of study, it is possible for AR to be a more natural means of acquiring new information with lower stress.

In addition, this experiment showed the characteristics of the brain's memory system when using the AR Teaching Materials to associate the imagery within the co-ordinate space with vocabulary. This reinforces the findings of the research conducted by Teshima et al. [8]. Their thesis "Development and Adaption of Augmented Reality for Children's Education" demonstrated the enhanced capability of children to learn place names and associate them with locations using AR. We believe that this shows great potential for AR technology to be used to learn place names and physical locations by association.

5 Future Work

Based on the experimental results discussed above, we support the hypothesis that "AR technology has the potential to be a more effective means of learning physical locations and names by means of association." For this investigation, we suggest the following learning materials:
(1) for studying the anatomy of an organism of a human or animal body, and (2) for memorizing complex mechanical structures, such as automobiles and ships.
By developing these and other AR teaching materials, we wish to validate the hypothesis by measuring brain activity and the efficacy of the teaching materials and confirming their relationship to one another.

Also, related to the opinions stating that the words in the AR teaching materials were too hard to read, there is a need to improve the system to make the characters easier to read on the AR display.

6 Summary

In this study, we conducted experiments to assess the efficacy of AR technology as a practical teaching tool using verification tests and focusing on the field of foreign language study. The results showed that there were no significant differences using AR Teaching Materials or Printed Teaching Materials.

However, in the experiments carried out to measure the brain activity of the subjects in the study, a significant difference was observed in the use of the two types of media. In this experiment, we found that the subjects' brains were more active while studying the Printed Teaching Materials than studying the AR Teaching Materials. We believe this shows that the AR method of study is overall a more natural one and, when compared to traditional methods of study, has the potential to be less stressful for the student.

In addition, the experimental results have resulted in a new hypothesis: "AR technology has the potential to be a more effective means of learning physical locations and names by means of association." We believe that this hypothesis warrants further investigation.

7 References

[1] D.W.F. van Kreveren and R. Poelman, "A Survey of Augmented Reality Technologies, Application and Limitations", The International Journal of Virtual Reality, 2010, 9(2) :1-20

[2] Rekimoto et al., "All about Augmented Reality", Nikkei Coomunicatio, NikkeiBP, 2009

[3] Akihito Kobayashi, "AR - Augmented Reality", Mainichi Communications, 2010

[4] Pan, Zhigeng et al., Transactions on Edutainment V, Lecture Notes in Computer Science, Vol. 6530, Springer 2011

[5] Yuan-Jen Chang et al. "INVESTIGATING STUDENTS' PERCEIVED SATISFACTION, BEHAVIORAL INTENTION, AND EFFECTIVENESS OF ENGLISH LEARNING USING AUGMENTED REALITY", IEEE, 2011

[6] Suya You and Ulrih Neumann, "Mobile Augmented Reality for Enhancing E-Learning and E-Business", IEEE, 2011

[7] Tomotsugu KONDO, "Educational Applications of Mixed Reality Technology and Current Issues", Technical report of IEICE, vol. 106, Institute of Electronics, Information and Communication Engineers, 45-50, 2006

[8] Yuji Teshima, Daisuke Kosigi, "A Development of Educational Materials for Children Using Augmented Reality", IEICE Transactions IEICE Transactions, Vol. J92-D, Institute of Electronics, Information and Communication Engineers, 2067-2071, 2009

[9] Masanori Sugimoto, "Learning Support Techniques in Augmented Reality Environment", Journal of JSAI, Vol. 23, The Japanese Society of Artificial Intelligence, 237-242, 2007

[10] Hirokazu Kato, "ARToolKit: Library for Vision-based Augmented Reality", Technical report of IEICE, Institute of Electronics, Information and Communication Engineers, PRMU 2001-232 (2002-2)

[11] Daisuke Harada, "New: Starting from Metasequoia", Gijyutsu hyoronnsa, 2009

[12] Kisou Kubota et al., "Learning and Brain", Saiensu-sha, 2007

[13] Kisou Kubota et al., "Thought and Brain", Saiensu-sha, 2005

[14] Shun-ichi AMARI, "Language and Thought in the Brain", University of Tokyo Press, 2008

[15] Baddeley, A. "Working Memory", Oxford University Press, 1986