Effectiveness of a Brain Science-Based Education Program for Improving Learning Capacity of Underachieving College Students

The purpose of this study is to verify the effectiveness of applying the brain science-based training program to students with underachievement in university. There were two research questions that were set to achieve this research goal. First, what is the result of the brain checking of the students who are subject to the academic warning? Second, what is the result of the post-learning ability test for the students subject to the academic warning after applying the brain science program for them? The results of the study were as follows. As a result of preliminary electroencephalography (EEG) of eight students with under-achievements, it was determined that the degree of the attention (four students) and concentration (four students) were respectively insufficient. Considering these results, the mode of the brain training system was set and the training program was conducted. In the students' participation in training, the degree of integrity in spatial perception, memory, and numeracy was found in all students in the 40 ~ 60 category, which means the average cognitive response level. The results of examining changes in neurophysiological brain waves by brain training system, that is, neurofeedback training, were as follows. First, there were some students whose average cognitive strength of instantaneous memory and response speed were located in the 40~60 categories, or more. Second, the results of the post-test in concentration was more positive than those of pre-test. Third, as a result of the brain stress test, the post-test in brain stress showed a more balanced work load than the pre-test. Fourth, the majority of students had high cerebral activity of left brain before training, but the balance activity between left and right brain increased after training. Based on the results, it could be concluded that the brain training program was effective to some extent for improving learning capacity underachieving college students.

Keywords: Underachievement, Brain science-based education program, Neurofeedback, Higher education

Introduction

About 12 percent of college students in OECD countries drop out before entering second grade (OECD, 2019), and as many as 40 percent in the United States drop out of college (Bustamante, 2019). In Korea, where passion for education is the highest in the world, the dropout rate of more than 4 percent of college students becomes a serious problem in college business administration. As a result of it, the dropout of college students at the micro level has influenced not only university business administration at the macro system level, but also deterioration of university education at the meso level. That is to say, it may bring out the failure of education system. College dropout remains an important policy issue. The major cause of this dropout has been cited as underachievement of university students.

Research on underachievement at universities has been carried out in the theme of poor learning (Davis, 1998; Baslanti & McCoach, 2006; Tavar & Simon, 2006; Balduf, 2009; Noh, et. al., 2011; Kweon & Song, 2016; Lee & Shin, 2017), characteristics of underachievers (Janos, et. al., 1986; Fong, 2014), analysis of learning support needs by type of underachievement (Noh, et. al., 2011), teaching strategies for underachievers (Highee, 1989), program development and effectiveness to improve learning capacity (Page, et. al., 2005; Yune, 2013).

Various efforts have been made to solve the problem of underachievement in learning. Recently, as science and technology have developed, brain science, or neuroscience[1] is nowadays being focused, suggesting that learning is changes in information, thoughts, and behaviors happening in the way that the relationship between neurons changes. Neuroscience has a view that the phenomenon of learning underachievement results from brain mechanism. It is expected that this approach may bring about new educational changes by considering brain science learning mechanisms, brain development characteristics, and interrelationships among body, emotion, and cognition learning beyond the existing behavioral, psychological, social, and educational perspectives (Jeong, 2011).

Students who suffer from learning underachievement do not reach a certain level of achievement due to various affective factors, despite having potential and normal intelligence. In particular, when considering their common characteristics of lack of attention and lack of self-confidence, affective factors such as concentration and motivation need to be interested. Due to the development of brain science, it becomes possible to directly grasp learners' affection, emotions and motivations, and it is recognized that a brain science approach can be helpful to the emotional aspects of underachievers (Lee, 2011). This claim is supported by a previous study (Park & Min, 2007) that the learning attitude of children with underachievement changed significantly through attention-focused strategies and learning motivation programs.

It is not easy to diagnose the exact cause of a problem in learning and to give a prescription to solve it, because learning is caused by complex variables such as cognitive, affective, and environmental characteristics (Hong, 2015). There has been a limitation that in-depth research cannot be made by the existing diagnostic methods such as simple learning counseling and self-statement based learning strategy tests for diagnosing causes of learning underachievement. In addition, the medium-to-large lecture-type programs conducted to improve the learning ability of underperforming students have been pointed out as having limitations in terms of the effectiveness because they mainly focus on cognitive approaches such as note-taking, exam preparation, and learning strategies. Therefore, a new attempt different from

[1]Neuroscience is a study of all nervous systems, including the brain. It seeks to reveal how we perceive and warn the external environment and how we interact with others. Genetics, biochemistry, physiology, pharmacology, pathology, etc., have a close relationship with the field of study (Jeong, 2011)

the current diagnosis method is required.

Especially, the interest for improving the effectiveness of brain science-based teaching and learning is on the increase. This means that interests in new perspectives that learning is the result of brain changes is increasing. The existing education system has been criticized for focusing on non-scientific approaches (Kim, 2006) and ideological approaches (Jang, Baek, Kim, & Hong, 2018). In order to overcome these limitations, 'science-based education' approach started to be considered. In this flow, especially ‘education service science’ and ‘learning science’ have been suggested. Education service science is one of efforts to change the education field into something more concrete and productive by combing the field of education with service science (Jang, Baek, Kim, & Hong, 2018; Kim & Baek, 2019; Kim, Baek, Hong, & Jang, 2019). Education service science is a methodology for improving the education service system, focusing on future-oriented improvement rather than an ideological perspective in approaching the educational phenomenon. In other words, it approaches education service as a service-oriented logic and attempts to derive education service innovation by rebuilding the current education service system and ultimately creating the value of learning experience. Education service science consists of five core elements: education service, education service dominant logic, education service system, education service innovation, and co-creation of learning experiences.

Learning science, which attempted a scientific approach to computer-based learning to streamline the learning process, comes into existence. It is an interdisciplinary field that works to further scientific, humanistic and critical theoretical understanding of learning as well as to engage in the design and implementation of learning innovations, and the improvement of instructional methodologies (Wikipedia, 2020). It is related with cognitive science, computer science, educational psychology, anthropology, and applied linguistics. It has dealt with not only the design of learning environments but also various psychological and critical theoretical foundations of human learning. It has established itself as an independent academic field as part of a systematic effort to identify and apply applications (Jeong, 2011). Learning science has become a major field in the field of cognitive science, and has developed into 'brain-based learning science' by fusion with the brain science field (Kim, 2006).

Brain-based learning science aims to design an optimal educational environment that can approach human thinking and learning processes in a scientific and systematic manner and to utilize the learner's brain efficiently based on scientific understanding of the brain's cognitive functions and structures. Education utilizing brain-based learning science has a goal to maximize learning by providing personalized education that fits learners' characteristics based on their understanding of the brain. In other words, it is one of the educational theories that enable learners and teachers to perform education and easily understand it by presenting instructional methods to all of them in a concrete and descriptive scientific way. Based on interdisciplinary approaches such as cognitive psychology, neuroscience (brain science), and

pedagogy, brain-based learning science helps brain effectively function by awakening the potential of learners and activating neuronal activity and the connection between the left and right hemispheres (Jeong, 2004).

With the development of brain science, a new educational paradigm has been attracted attention as it seeks to establish ways to improve creativity, character, and learning through the convergence of brain science and education. This is why the development of new efficient learning and teaching methods based on the characteristics of human brain functions, namely brain training and brain education, is becoming important (Jeong, 2011). Therefore, the brain science-based education program for undergraduate students is expected to help improve the quality of college education by improving the dropout rate.

The purpose of this study is to verify the effectiveness of a brain training system, a neurofeedback to underachieving undergraduate students who receive academic warning, to provide educational implications for the development of new programs to improve college students' learning ability. The research questions were as follows. First, what is the result of the brain checking of the students who are subject to the academic warning? Second, what is the result of the post-learning ability test for the students subject to the academic warning after applying the brain science program for them?

Brain science-based education and improvement of learning in higher education

Brain science and learning innovation

Brain science and learning

Brain science or neuroscience defines that learning is changes in the relationship among neurons and in information, thinking, and behaviors. In other words, learning at the perspective of the brain science involves the operation of complex factors such as cognitive functional factors (e.g., memory, concentration, thinking, logical reasoning, etc.), neurophysiological changes (e.g., physical activity, etc.), emotional state recognition and control ability (e.g., emotional response, etc.). The brain science approach to learning shows the possibility of more systematic and scientific analysis of human learning because it deals with learning in terms of human brain function and development (Jeong, 2011).

Efforts to utilize brain science in education have been made steadily. The convergence study of brain science and education began in earnest by the Brain and Learning Project promoted by the Center for Educational Research and Innovation, OECD for three years from 1999 to 2002. The Society for Neuroscience (SfN) has been conducting researches to connect neuroscience with education, and through the neuroscientist-teacher partnership program, it has also built an online system to apply the expertise of brain science to school education websites (Jeong, 2011). Harvard Graduate School opened the 'Master of Education: Mind, Brain and Education' course to study cognition,

neuroscience, memory, teaching & learning, and emotional development. This effort to converge brain science and education has been established, in particular, as an independent discipline of learning science. Learning science has become a major field in cognitive science, and has developed into 'brain-based learning science', converging with the brain science field (Kim, 2006). Brain-based learning science aims to design an optimal teaching and learning environment that can approach human thinking and learning processes in a scientific and systematic manner and utilize the learner's brain efficiently based on scientific understanding of the brain's cognitive functions and structures.

In the field of brain science, learning is the process of identifying information patterns (pattern seeking) and automating them through frequent use. That is, brain-based learning can be explained by pattern finding and programming. Pattern finding is an activity that categorizes objects, procedures, systems, relationships, and situations. It is a process of exploring, identifying, and understanding information. The brain uses past experiences to recognize types of information and to grasp meanings. The brain keeps the information in the working memory, and at the same time, searches the learner's long-term memory to find prior knowledge or background knowledge for pattern identification of new information. When the brain finds the information, it calls those into working memory and cross-references those to identify and understand new patterns of information. A series of pattern-finding processes of exploration, identification, and understanding is a process of learning and a source of insight and creativity.

Automation or programming means the ability to practice what you understand to achieve a goal and use it repeatedly in a certain order. At first, the program is used through conscious effort with guidance or help, but through practice, it is possible to execute almost automatically such as arithmetic operations and writing essays. Finding patterns to identify and understand information patterns is a key process of input, and programming, an automated process, is a key process of output.

How the brain processes electrical signals from neurons has not yet been clarified, and the brain's function according to its anatomical location is explained based on the researchers' experience. For example, the visual cortex in the posterior occipital lobe of the brain processes visual information, and the sensory cortex and motor cortex located in the middle, process information related to sensory and motor commands. In addition, the auditory cortex located in the temporal lobe, Broca's area, and Wernicke's area are known to be responsible for hearing-related signals and language-related functions (Bear, Connors & Paradiso, 2007). Through these empirical foundations and EEG measurement experiments, the academic world classifies anatomical functions and understands the brain. However, some criticizes that the brain function modeling is trying to understand the brain's information processing process as a model that is too simplified.

Memory and Learning

When assuming that remembering information is learning, it is important to make the information a form that can be remembered. This is because knowledge or information that passes without a certain form or direction is not remembered. Representative methods of making information into a memorable form include symmetry and modularization (Park, 2008).

Symmetry is a strategy to clarify ambiguous knowledge by arranging structures that change in various forms into a single symmetrical structure. This is an easy and quick way of remembering information without reducing it. Furthermore, it is not just a temporary aid to memory, but a learning method to uncover the laws of nature. For example, a sentence with a symmetrical structure may be remembered for a long time, and a symmetrical rectangle is easier to remember than an irregular shape. Knowledge lacking in symmetry is difficult to connect to each other to form higher-order knowledge structures.

Modularization is a method of storing the learned content as a single knowledge. When the memory is modularized, it can be stored, transferred and manipulated like bottled water, so that the memory can be kept for long without forgetting. Modularization of memory is a process that combines well-learned contents into a lump of solid meaning, and the modularized memory classified as meaning can be variously combined like a LEGO block. Forming a module makes the scope of knowledge clear, and the boundaries between knowing and not knowing make what to learn next clear. Eventually, learners have self-directed learning skills.

Eventually, if the memorable information is transformed into symmetrical and modular structure, remembering it can be easy and the information lasts for a long time. If a structure is symmetrical, it is easy to construct a module. And if a large single structure with symmetry is decomposed into component modules, the components can be arranged in order in time and space. The phenomenon in which the module components are arranged in chronological order becomes the process of developing events and objects.

Emotion and Learning

A lot of information is remembered and discarded through learning. And emotions also make a distinction between remembering and not remembering. Emotions filter out insignificant information and dominate the senses. The ability to control positive emotions is considered to be an important factor for improving learning abilities (Jeong, 2011). The fact that the self-control ability is more significant than intelligence as a factor influencing learning achievements also supports this claim. Therefore, it is important to develop the ability to suppress impulses and immediate satisfaction, to focus on one task, and to understand one's thoughts and feelings in developing learning skills. Emotion affects all processes of learning and has an important influence on the continuity of learning. In particular, it is important to form an emotional circuit that feels the joy achieved through learning. Emotional power is inevitable in

learning because conscious decisions and actions necessarily involve the process of emotion.

The relationship between emotion and learning can be explained in terms of brain science. The brain frontal lobe, which is involved in word search, anecdotal memory, work memory, and meta memory system, is connected to the cerebral limbic system responsible for emotions. In order to activate the frontal lobe, it is necessary to control negative emotions through suppressing excessive activity of the limbic system by strengthening positive emotions. Therefore, it can be judged that forming positive emotions helps improve learning ability.

Brain-based education and training system

A representative brain-based education and training system is Neurofeedback. Neurofeedback training, a type of brain-based training, has evolved dramatically since Hans Berger first discovered brain waves in 1924. Neurofeedback training was effective in cognitive therapy in patients with attention deficit, hyperactivity disorder, anxiety disorder, and brain damage. And the effectiveness of neurofeedback training in normal people's performance, attention and learning ability was reported (Lubar, 1999; Kropp, Siniatchkin, & Gerber, 2002; Fox, Tharp, & Fox, 2005). With the development of brain science, the technology is gradually spreading from the medical field to the educational field.

Neurofeedback

Since humans are not sufficiently aware of their physiological signals, it is difficult to judge whether their attempts to alleviate negative signals are successful. Biofeedback was designed to help the limit of the human cognitive ability. Biofeedback using brain waves is a neurofeedback. This is a training technique using electroencephalogram (EEG), and is a behavioral cognitive therapy-based brain training technology to control the brain waves necessary for brain development while directly checking brain waves information. In addition to measuring psychophysiological phenomena that are difficult for individuals to recognize under normal circumstances, Neurofeedback helps information easy to understand by displaying it through computer screens or other tools. While directly observing the signal presented through the computer, a learner experiences what kind of effort can change the signal and finds the optimal method by directly adjusting it (Fuller, 1984).

EEG, which measures the electrical signals generated when exchanging information between brain neurons, shows the brain's developmental state, active state, balance state, psychological state, emotional state, attention concentration ability, rest ability, and learning ability. The brain function analysis method using the EEG is distinguished from indirect analysis through questionnaire and problem solving methods such as existing IQ test, aptitude

test, and personality test. Because it is quantitatively analyzed by measuring EEG, it can be said to be much more objective and scientific than the existing analysis methods.

The key principle of neurofeedback is that changing the brain waves associated with increasing or decreasing mental activity can change the human mind. Neurofeedback, which focuses on changes in human brain activity, started with Pavlov's Conditioning Response, Thorndike's law of effect, and Skinner's shaping principle.

Before training starts, EEG is a mixture of waveforms of various frequency bands. When the trainee's intended form of brain waves is formed (e.g., bending the spoon, the central target), it is selectively strengthened through computer screen information, and a trainee is learned that the training goes wrong by taking disappointing results (e.g., no change, low score of targeting) when unexpected types of brainwave activities occur. When the training for selectively compensating for only the EEG of a specific frequency band is repeated based on the law of effect, the EEG shape of the trainee is changed in a specific direction. Neurofeedback training proceeds gradually. In the initial training phase, compensation is provided even when a specific frequency occurs at a low intensity. As training progresses, the targets are adjusted upwards, providing compensation only when a certain frequency of EEG occurs at the trainee's intended level of intensity. The shaping principle of changing behavior through step-by-step rewards for target behavior is applied. The laws of effect and shaping principle are based on the principles of instrumental and operational conditioning, in which the outcome of an action determines the frequency of its occurrence.

Neuro Harmony

Neuro Harmony is a neurofeedback device using brain waves. After analyzing brain waves, Neuro Harmony aims to make the trainee’s brain train its own brain. After measuring the EEG of the trainee, it finds out and informs the EEG state he or she needs. For example, when perceived by sound or video, the trainee's brain learns and trains itself to maintain the state of realizing what the state needs.

The goal of training with Neuro Harmony is the optimization of the trainee’s brain. Neuro Harmony is not training to strengthen only certain brain waves. It takes efforts to induce brain balance and harmony to make brain functions healthy and optimized. The brain has plasticity. When given a suitable stimulus, it undergoes dynamic and continuous changes. In addition, as the frequency increases and brain activity becomes active during neurofeedback training, more blood flows to the area, thereby nutrients in the blood strengthen and reorganize existing connections. Neuro Harmony increases the self-regulating ability of cells and increases the stability and flexibility of brain cells in the area, that is, the ability to move between various mental states, for example, from sleeping to arousal or from excited state to relaxation.

Neuro Harmony is a two-channel EEG measuring instrument that simultaneously measures left and right brains according to unipolar induction by attaching electrodes to the frontal lobes of the left and right brains. It consists of a computer program called Neurosoft and Neurospectrum.

The method of measuring EEG through Neuro Harmony is performed by comparing EEG patterns in the trainee's open and close eyes, and comparing the differences to determine the relaxation and stability of the mind and body. Basic rhythm can be grasped by comparing EEG in open eyes with that in close eyes. The basic rhythm of brain waves generated in opening and closing eyes, wakefulness, and stable state varies with age. It determines the degree of brain development and brain aging because the range of the rhythm of brain waves according to age is classified to some extent. In addition, it is possible to grasp the activity level, attention concentration, emotional state, and stress resistance of the brain based on the measured correlation between the EEG bands.

After measuring EEG, the 'mind picture' which is included in Neurosoft, analyzes self-regulation ability by measuring rest, tension, attention, and concentration for 1 minute respectively. 'Mind picture' program analyzes the relative ratio of alpha wave, sensorimotor rhythm (SMR) wave, and low beta wave reflecting the activity state (relaxation, attention, concentration) during awakening, and it can grasp the ability of the trainee to control his or her brain condition. The frequency with the lowest relative ratio among the EEGs fed back by the trainee is the training mode of him or her.

The most important thing in neurofeedback training through Neuro Harmony is to choose the training mode which is needed. The training mode refers to the EEG state that induces a specific mental state. Neuro Harmony has eight training modes, including relaxation, attention, concentration, left and right brain balance, memory, creativity, self-regulation, and meditation.

Rest, attention, concentration, and left & right brain balance are called basic training modes. And memory, creativity, self-regulation, and meditation are called special training modes. The basic training mode is for brain stability, awakening, and activation. The training mode is determined through the Self-regulation Analyzer in the Neurosoft provided by computer program. The special training mode can be used after a trainee reaches a certain level through a basic training mode.

Table 1. Training Mode

	Mode	Characteristics
Basic Training	Rest (Alpha)	It strengthens alpha waves and it improves brain stability, rest ability, overall balance
	Attention (SMR)	It is a SMR reinforcement training. It is the ability to respond to information coming from outside.
	Concentration (Beta)	It is a beta-wave strengthening training. It is the ability to increase activity as a brain active state and to fix concentration to one thing

	Left and right brain balance (SMR/Beta)	It is a training for a left and right brain symmetry.
Special Training	memory creativity self-regulation meditation	It is a training of psychological stability and deep consciousness by inducing the expansion of internal consciousness through alpha / theta training

The training program consists of a total of fifteen trainings including brain relaxation, brain tension, memory, thinking ability, and meditation. There are five training programs for brain relaxation training, including cup making, flower blooming, sunflower, and spoon bending. Brain tension training includes shooting arrows. Memory training is a program to remember planets, and thinking ability training includes a jigsaw puzzle activity. Meditation training is composed of three kinds of activities: sun meditation, aura, and levitation.

Method

Participants

This research started with eight college students who were underachievers who received bachelor warnings twice consecutively, but two of them (Kwa○○, K○○)[2] was not able to participate until the end due to personal circumstances.

The research was conducted for two weeks. In order to minimize the ethical issues that may occur in the research process and protect the interests of participants, the research purpose and contents were presented in detail through telephone calls and prior approval for participation was received in advance. After receiving the consent to collect and use personal information face-to-face from the students, the research was conducted. The basic information about the students participating in the study was as follows.

Table 2. Information of Participants

Participant	Gender	Details
Y○○	Female	
O○○	Female	
K○○	Female	Dropping out during experiments
Kw○○	Female	
Kwa○○	Male	Dropping out during experiments
A○○	Female	
J○○	Male	

[2]Originally, the participants started with 8 students, but 2 of them (Kwa ○○, K○○) during the experiment were unable to participate until the end due to personal circumstances.

S○○	Male	

Setting of training mode based on the results of pre-EEG

Before the neurofeedback training, a brain function assessment (BFA) was conducted. And BFA was re-executed after conducting neurofeedback training. As a result of measuring the self-regulated ability of the brain's autonomic nervous system for each participant, it was found that all participating students had a problem in terms of 'attention and concentration', and accordingly, the training mode was set as follows.

Table 3. Measurement of EEG self-regulated ability and training mode setting

	Self regulated ability			Training Mode
	Relaxation	Attention	Concentration	
Y○○	38.1	18.0	19.0	Attention
O○○	33.1	23.5	26.4	Attention
K○○	No showing, although re-test is required			Attention
Kw○○	23.6	18.4	21.6	Attention
Kwa○○	28.6	20.4	16.4	Concentration
A○○	28.6	18.2	18.1	Concentration
J○○	31.8	31.8	23.5	Concentration
S○○	25.5	20.6	18.3	Concentration

Positive response rate before and after neurofeedback training

Looking at the result trend of the pre- and post-positive response rate (test integrity) by learning cognitive function of the spatial perception, memory, and numeracy of the participating students, most of them were located in the 40 ~ 60 category, which is the average cognitive response value in performing brain learning ability tests using brain waves. Some of them were located higher. The detailed results were as follows.

Table 4. Positive response rate (test integrity) of spatial perception, memory, and numeracy

	Spatial perception		Memory		Numeracy	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Y○○	67	67	73	57	57	67
O○○	73	67	67	67	41	73
K○○	57	-	73	-	67	-
Kw○○	67	67	67	57	73	73
Kwa○○	67	-	73	-	73	-
A○○	73	67	67	62	73	62
J○○	73	73	51	62	62	73

S○○	73	73	67	62	73	46

In the case of J○○, overall positive reaction rate (correct answer rate) in post-test was on the increase more than that of pre-test, and it means that post-test performed more faithfully than pre-test. The positive reaction of Y○○ and O○○, showed an increasing trend, but the spatial and memory showed the same or decreased trend as before. It seems to have influenced the positive reaction due to various causes including psychology at the beginning of the cognitive response test. The results of the post-tests in S○○ and Kw○○ were the same or decreased, and A○ was found to have decreased in all cognitive response results in the post-test than before, due to personal or other personal reasons during the post-test. It can be inferred that the tests were not conducted stably. In case of K○○ and Kwa○○, the results of pre- and post tests were unable to be compared, due to abandonment. In the preliminary examination, it was judged that there was no problem with background knowledge and performance integrity.

Wilcoxon signed rank tests did not yield any significant differences between the pre-and post–values: spatial perception (Z=-1.414, p=0.157), memory (Z=-0.948, p=0.343), numeracy (Z=-0.271, p=.788).

Measuring tool

A BFA (Brain Functions Assessment) test was conducted to diagnose pre- and post-learning skills of underachieving students. This test comprehensively analyzes neurophysiological indicators of cognitive ability and concentration from brain waves measured by solving the problems presented. In other words, by measuring the EEG generated during the process of performing stability, wakefulness, memory, spatial perception, and numeracy test, positive response rate, false response rate, instantaneous memory, judgment speed, concentration, brain stress, left and right brain activity level are quantified. EEG is measured while the cognitive process is performed in the order of perception, memory, calculation, reasoning, judgment, and reaction for 12 minutes.

Figure 1. Sample screens of a variety of test

Wakefulness test | Spatial perception test | Memory test | Numeracy test

Procedures

This study was conducted by the following research procedure. First, previous studies on the relationship between brain science and education were analyzed and synthesized. Second, a brain checking was conducted for underachievers. The pre-test was conducted by 5 experts (4 brain counselors, 1 brain educator) who belong to a research institute for the private brain science-based program with years of experience in neurofeedback training. Third, the brain science training program [3] using neuroharmony, a neurofeedback device for underachievers was applied. Training was conducted to improve learning ability based on individual measurement results through brain learning ability tests. Brain learning ability training, that is, brain-based training, consists of neuroscientific training, visual perception training, auditory perception training, and sensorimotor training. Neurofeedback training was also conducted by 5 experts (4 brain counselors, 1 brain educator), and brief consultations were conducted during the training to understand the situation of participants. In consideration of the characteristics of this project, two types of spoon bending and arrow shooting training programs were selected, and the training schedule was set as shown in the table below.

Table 5. Training program schedule

Term	1st term		2nd term		3rd term		4th term	
Activity	Orientation **Pre-EEG test**	Measurement of Self Regulated Ability	**Training 1** Bending Spoon (5 times)	Individual Interview	**Training 3** Bending Spoon (10 times)	**Training 4** Shooting arrows (10 times)	**Training 5** Bending Spoon (5 times)	**Post-EEG test**
		Decision of Training Mode	**Training 2** Shooting arrows (5 times)				**Training 6** Shooting arrows (5th times)	

Fourth, post-learning ability (EEG) tests were conducted for the underachievers. The post-tests were conducted by 4 experts (4 brain counselor, 1 brain educator) with years of experience in neurofeedback training from a private research institute for brain science-based program.

Fifth, based on the results of the application of the brain science program, educational implications for improving the learning ability of underachieved students in college were drawn.

[3]Neurofeedback training, a neuroscientific training, was conducted in consideration of the lack of prior information on the causes of poor learning among students participating in this research project, the limitation of the number and time of training available, and the age of participants in the late adolescence.

Results

Before the full-scale training began, pre-electroencephalography(EEG) was performed to analyze the brain utilization status of underachieving students who received learning warnings and to set the neurofeedback training mode. Neurofeedback training was conducted based on the results of the pre-EEG tests, followed by post-EEG tests. The results were as follows.

Neurophysiological EEG Change by Neurofeedback Training

Before and after neurofeedback training, detailed analysis results of brain neurophysiological EEG output indicators (cognitive strength, judgment speed, concentration, brain stress, left and right brain balance) of the underachievers were as follows.

1) Cognitive strength

Cognitive strength evaluates the excellent degree of perceptual ability, short-term memory, long-term memory, recognition and reasoning ability, which are high-order cognitive functions, through instant memory of event (problem) responses among neurophysiological indicators of EEG. It is interpreted that the higher the cognitive strength, the better the perception ability, short-term memory, long-term memory, recognition and reasoning ability corresponding to the higher-order cognitive function. In conducting the BFA (Brain Functions Assessment), brain learning ability test using EEG, all of the participating students were located within the average instantaneous memory cognitive intensity value of 40 ~ 60 or higher[4].

Wilcoxon signed rank tests did not yield any significant differences between the pre-and post –values: spatial perception (Z=-.314, p=.753), memory (Z=-1.572, p=.116), numeracy (Z=-.524, p=.600).

Table 6. Changes in pre- and post-cognitive strength response rates

	Cognitive Strength					
	Spatial Perception		Memory		Numeracy	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Y○○	77	65	50	78	57	71
O○○	73	76	54	98	66	68
K○○	88	-	80	-	88	-
Kw○○	66	99	43	99	66	88
Kwa○○	90	-	86	-	60	-
A○○	88	74	56	68	57	54
J○○	80	85	92	76	86	99

[4]The scores of EEG tests which are performed on samples similar with subjects' conditions such as region, age, and time are quantified and standardized. The standard range (40 ~ 60%) of standardized indicators is set to prepare standards for interpretation of relative indicators.

S○○	76	85	71	75	99	43

2) Response speed

For determining the effectiveness of the neurofeedback training program, response speed[5] can be considered. It means that the faster the cognitive speed, the faster the information processing speed of the brain. In conducting the BFA brain learning ability test using EEG, all of the participating students were located within the average judgment speed value of 40 ~ 60 or higher.

Wilcoxon Signed-Ranks test indicated that there was no statistical difference between pre-and post –values: spatial perception (Z=-1.054, p=.292), memory (Z=-1.157, p=.249), numeracy (Z=-1.153, p=.249).

Table 7. Changes between pre- and post-test of response speed

	Response Speed					
	Spatial Perception		Memory		Numeracy	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Y○○	65	75	50	63	71	73
O○○	69	72	60	62	71	66
K○○	55	-	68	-	65	-
Kw○○	70	64	66	55	64	76
Kwa○○	77	-	60	-	69	-
A○○	60	63	59	62	61	55
J○○	71	70	48	49	55	71
S○○	59	65	48	55	58	72

3) Concentration

The concentration is important for grasping the training results of students' self-regulating brain function of nervous system for highly cognitive response. The concentration response rate consists of the 'attention ability' that alerts the surroundings and the ability to pay attention to the specific target. As a result of the training mode focused on the attention and concentration of the participants, which were weak in general, a positive effect appeared. As a result of the post-brain learning ability test using brain waves, all participants were located within the average number of 40-60, or higher.

Wilcoxon signed rank tests did not yield any significant differences between the pre-and post–values (spatial perception, Z=-1.261, p=.207; numeracy, Z=-1.172, p=.116), except memory (Z=-2.023, p=.043).

[5]The speed of response refers to the speed at which the cognitive process is processed in the brain and is determined by the time the response key is pressed.

Table 8. Changes between pre- and post-test of concentration reaction rates

	Concentration					
	Spatial Perception		Memory		Numeracy	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Y○○	45	43	41	44	46	53
O○○	34	50	38	49	48	51
K○○	47	-	48	-	49	-
Kw○○	47	58	49	53	46	59
Kwa○○	45	-	40	-	45	-
A○○	60	55	55	61	54	63
J○○	63	65	55	55	63	55
S○○	37	54	35	55	40	51

4) Brain stress

Brain stress (workload) is the level of mental workload experienced when performing a test task, and it refers to the state of arousal in which rapid waves appear. Normally, when people are emotionally anxious, nervous, nervous or overly awakened, they have a mental stress level that is higher than the standard range.

In conducting the BFA brain learning ability test using EEG, most of the participating students showed a low level of normal brain stress during the pre-test. Students who performed both pre-test and post-test showed a more balanced workload in post-test than post-test. The results of each student on the workload response rate indicating the normal stress level and the level of arousal level felt when performing each question-type test were as follows.

Wilcoxon Signed-Ranks test indicated that there was statistical difference between pre-and post–values (spatial perception, Z=-2.023, p=.043; memory, Z=-2.214, p=.027), except numeracy (Z=-1.261, p=.207).

Table 9. Changes between pre- and post-test of brain stress

	Brain Stress					
	Spatial Perception		Memory		Numeracy	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Y○○	38	44	41	43	38	41
O○○	32	42	35	41	36	38
K○○	32	-	29	-	28	-
Kw○○	31	35	35	36	31	36
Kwa○○	47	-	45	-	48	-
A○○	71	74	67	73	65	72
J○○	52	52	47	49	54	47
S○○	38	51	35	53	31	50

5) Left and right brain activity

Most of the participating students were dominated by left brain activity in the pre-test of BFA, brain learning ability using brain waves. For some students, left brain activity was dominant in the post-test. But in most cases, left and right brain balance activity and right brain activity were predominant.

When performing tasks on the perception, memory, reasoning, judgment, and response tasks of the cognitive process sequentially, the results of the left and right brain activity tests were as follows.

Wilcoxon Signed-Ranks test indicated that there was no statistical difference between pre-and post –values for left and right brain activity; Spatial perception test (left brain, Z=-.271, p=.786; right brain, Z=-.271, p=.786), memory test (left brain, Z=-.734, p=.463; right brain, Z=-.734, p=.463), numeracy test (left brain, Z=-1.472, p=.141; right brain, Z=-1.363, p=.173)

Table 10. Changes between pre- and post-test of left and right brain activity

	Left & Right Brain Activity											
	Spatial Perception				Memory				Numeracy			
	Pre-test		Post-test		Pre-test		Post-test		Pre-test		Post-test	
	L	R	L	R	L	R	L	R	L	R	L	R
Y○○	58	41	63	36	59	40	71	28	60	39	72	28
O○○	62	37	51	48	62	37	40	59	62	46	46	53
K○○	53	46	-	-	56	43	-	-	58	41	-	-
Kw○○	63	36	78	21	64	35	72	27	68	31	66	33
Kwa○○	52	47	-	-	56	43	-	-	49	50	-	-
A○○	60	39	55	44	57	42	51	48	56	43	53	46
J○○	49	50	51	48	51	48	33	66	57	42	23	76
S○○	51	48	51	48	52	47	49	50	57	42	45	54

Summary of Results by Participants

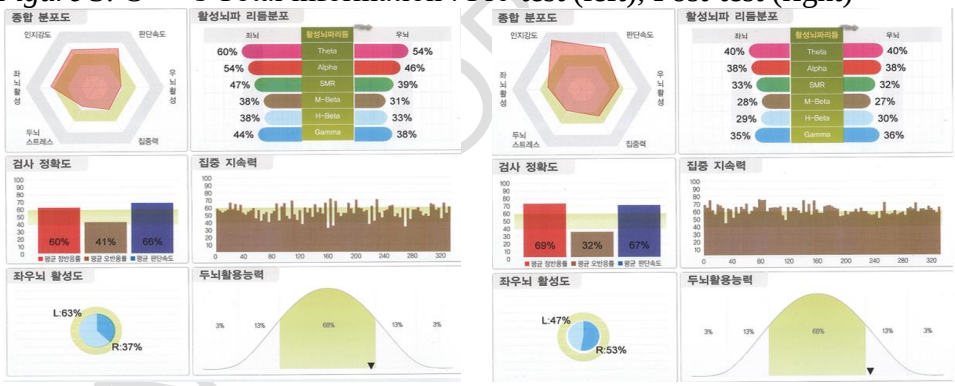
In case of Y○○**,** during the cognitive activity, the appearance of theta waves is more prevalent among slow waves that appear when you are drowsy or weak in consciousness, at ‘the active brain wave rhythm distribution’, which shows the distribution of active EEG waveforms.

Figure 2. Y○○’s Total information: Pre-test (left), Post-test (right)

The strength of the gamma wave is also superior. Therefore, Y○○ may show helplessness, tiredness, and sometimes acute and nervous brain tendencies in daily life patterns through the rhythm of the active brain waves. The concentration was higher in the post-test, and it was found that the positive will was reflected in the training process when looking at the figures to maintain concentration until the end. Compared to the pre-test at the brain ability level, the result of the ability utilizing the brain at the post-test was adjusted upward to the right, which means that it is positive. Both the pre- and post-tests show that the left brain is dominant, showing a high level of rational effort and willingness. The value of the positive response rate(correct answer rate) shows that the will to practice faithfully in both the pre- and post-tests was maintained. As a result, as shown in the general distribution diagram, in order to improve the learning deficiency of Y○○, efforts to activate a balanced rhythm such as right brain, concentration, and brain stress are required.

In case of **O○○, t**he distribution of the active brain wave rhythm shows the overall standard range or less. The emergence of theta and alpha waves which are slow, is relatively strong in both pre- and post-test. And gamma reflecting subjective cognition among mental waves that perform mental tasks such as mental arithmetic and reasoning, or waveforms, is strong. This can lead to a sensitive tendency to tired brain conditions and emotions.

Figure 3. O○○'s Total information : Pre-test (left), Post-test (right)



In terms of 'concentration', the value of post-test were more stable than that of pre-test. It seems that she did her best until the end of the task. It is positive that ability utilizing a brain was adjusted to the right at 'the brain ability level'. The ratio of 'left and right brain activity' showed that the left brain was more predominant in the pre-test, but the right brain was more predominant in the post-test. It can be seen from the positive response rate (correct answer rate) that the accuracy of the test was performed more faithfully in the post-test than pre-test. As a result, the activation level of right brain, concentration, and brain stress among the brain learning abilities was weaker than that of the left brain, judgment speed, and cognitive strength. But the training result was the best among the participants. A positive mindset and reinforcement of physical strength and brain power are required to promote learning.

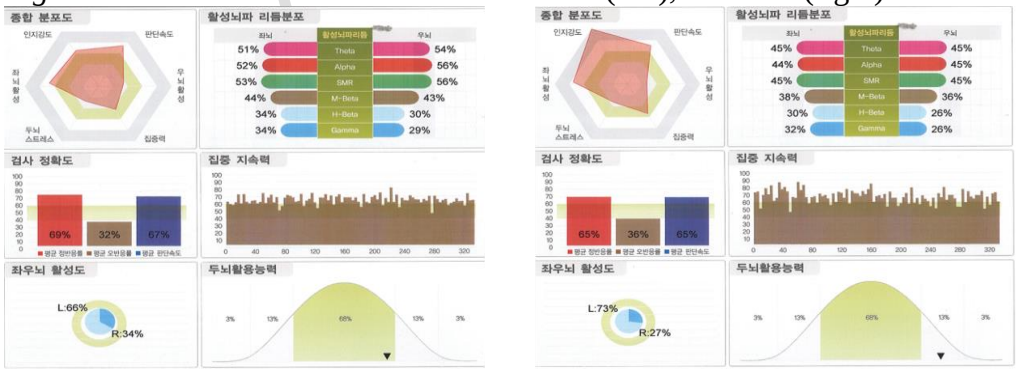
In case of K○○**, i**n the active EEG rhythm distribution, it was a stable rhythmic distribution as a whole, but the slow brain waves were strong.

Figure 4. K○○'s Total information : Pre-test

In particular, it can be seen that SMR(Sensori Motor Rhythm) is strong. Therefore, emotional tendencies, which are sensitive to the surrounding environment and complex or unreasonable, high cognitive function thinking activities, may tend to avoid them. Concentration may tend to be jittery due to the type of task and the influence of her emotions. Brain ability level is high in the positive direction. The left and right brain activity and the accuracy of the test did not show a unique situation, but showed stable values. As a result, the overall distribution was stable, but the workload (stress) was lower than the standard range.

In the active EEG rhythm distribution, Kw○○**'s** post-test showed overall low values based on the standard range, but in the pre-and post-test, theta and alpha which are slow waves showed strength.

Figure 5. Kw○○'s Total information : Pre-test (left), Post-test (right)



However, since the value of SMR indicating the main waveform of attention is the highest, it may have a brain tendency to increase fatigue. In both pre-and post-tests, the appearance of rapid brain waves is weak, so there is a sense of stability, but it is not complicated or rational with emotional tendencies that are sensitive to the surrounding environment, and may tend to avoid high cognitive thinking activities. Concentration was higher in the post-test, and it can be seen that the positive will was reflected in the training

process when looking at the figures to maintain concentration until the end. Compared to the pre-test at the brain ability level, the result of the brain utilization ability at the post-test was adjusted upward to the right, which means that it is positive. In the left and right brain activity, the left brain was more predominant. In the accuracy of the test, the value of the positive response rate(correct answer rate) decreased slightly in the post-test. As a result, it can be seen that the right brain activity and the workload are weakly indicated in the comprehensive distribution chart, so that efforts for comprehensive and intensive finishing of learning are required.

In case of Kwa○○**, t**he active EEG rhythm distribution is stable and active as a whole, but the gamma reflecting the subjective cognition and the SMR that is conscious or vigilant around the periphery appears to be stronger.

Figure 6. Kwa○○'s Total information : Pre-test

Therefore, it feels stable, but it may be prone to avoid feelings that are uncomfortable and highly cognitive thoughts and activities that are not complex or rational and emotionally sensitive to the surrounding environment. Concentration may tend to be jittery due to the type of task and the influence of your emotions. The left and right brain activity and the accuracy of the test did not show a unique situation, but showed stable values. As a result, the overall distribution was stable, but the concentration and workload were weakly across the standard range, indicating that his immersion may be weak.

A○○'s active EEG rhythm distribution shows similar rhythms and figures overall in the post-test, but in pre-and post-test, she may be in sensitive emotional state and nervousness due to the strong appearance of fast brain waves. Her higher concentration retention in post-test showed that she had the tendency to do the best until the end when performing tasks. The brain skill level is located in the standard range. The left brains were more predominant. And the fact that circle size of the left and right brain activities became larger, means that the gamma wave activity influenced the brain energy consumption when performing tasks.

Figure 7. A○○'s information : Pre-test (left), Post-test (right)

The difference in the value of positive response rate (correct answer rate) of the test accuracy is not large. But the positive response rate's value indicates that the pre-test was performed more faithfully than the post-test. As a result, looking at the general distribution, the brain learning ability of the right brain was relatively weak. It can be seen that physical fitness and self-regulation management are required.

In J○○'s active EEG rhythm distribution, the overall level of post-test was low. In both pre- and post-tests, the appearance of gamma waves among fast brain waves is relatively strong. Therefore, unstable brain utilization ability, nervous sensitivity, and emotional sensitivity may appear.

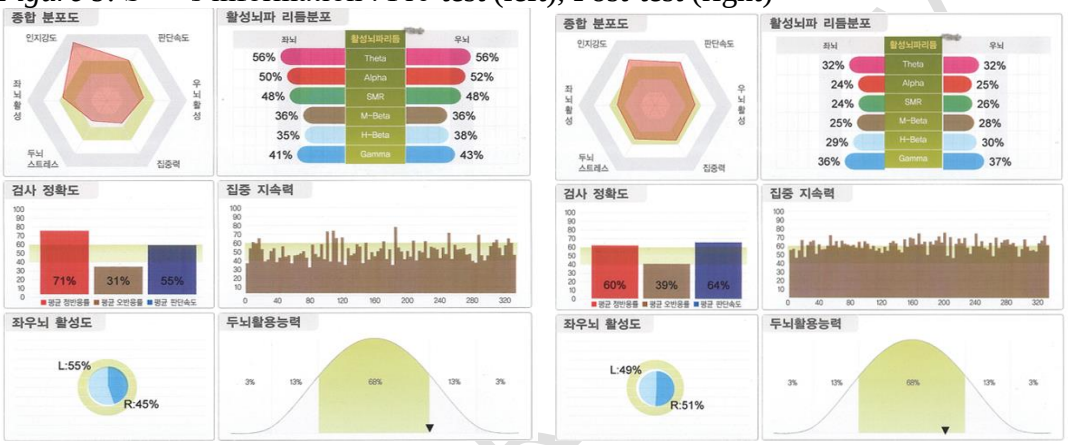
Figure 8. J○○'s information : Pre-test (left), Post-test (right)

The concentration was higher in the post-test, but in the numeracy, which is the latter part of the assignment, the concentration value decreased, indicating an unstable concentration retention. The brain ability level was adjusted upward in the positive right direction. The ratio of left and right brain activation was balanced in the pre-test, but the right brain was predominant in the post-test. Given the post-test situation, a sharp imbalance in brain ability control happened due to a burden on the task performance. It can be seen from the positive response rate (correct answer rate) that the accuracy of the test was performed more faithfully in the post-test than pre-test. As a result, it can be

seen that in the brain learning ability, the imbalance due to the relative resistance of the left brain and the overall value of the active brain rhythm distribution are less than the standard range.

S○○'s post-test in the active EEG rhythm distribution showed low values below the standard range. Theta wave, a slow brain wave, was strong in the pre-and post-test. Gamma wave, which is related with mental works such as mental arithmetic and reasoning, also was strong. Therefore, These indicated that there is a brain inclination that can show fatigue, emotional sensitivity, and nervous sensitivity.

Figure 9. S○○'s information : Pre-test (left), Post-test (right)



Concentration was higher in the post-test than pre-test. His higher concentration retention in post-test showed that he had the tendency to do the best until the end when performing tasks. In the post-test, the brain ability level was adjusted to the left, which may be slow or negative when performing tasks. This result indicated that negative attention to the burden of task performance and the lack of self-regulation were brought. The ratio of left and right brain activity was balanced in both pre-and post-tests. So it could be expected that he might have a brain skill to solve the ideal problem. It can be seen from the positive response rate (correct answer rate) that the accuracy of the test was performed more faithfully in the pre-test than post-test. As a result, when looking at the overall distribution, it was found that the training result was more positive at the post-test, comparing the pre-test. Efforts to reach an appropriate level of workload are required.

Conclusion

This study aims to verify the effectiveness of a brain science-based training program by applying using a kind of neurofeedback, brain-based training system to underachieved students who have received academic warnings. The results of the study were as follows. As a result of preliminary electroencephalography (EEG) of eight students with underachievers who participated in the study, it was determined that most of the attention (four

students) and concentration (four students) areas were insufficient. According to these results, the mode of the brain training system was set and the training program was conducted. Spatial perception, memory, and numeracy of all students were located in the average cognitive response level of 40 ~ 60.

The results of examining changes in neurophysiological brain waves by brain training system, that is, neurofeedback training, were as follows. First, there was a student whose average instantaneous memory cognitive strength and judgment speed response value was located in the 40 ~ 60 section or showed more than that. Second, the results of the post-test showed that the concentration of students was more positive than those of the pre-test. Third, as a result of the brain stress test, the post-test showed a more balanced workload than the pre-test. Fourth, the majority of students had high cerebral activity before and after training, but the balance activity between left and right brain increased after training.

Based on the results of the above study, it is considered that the brain training program for the students with underachievement in learning was effective to some extent. Based on this research conclusion, the following are suggestions for university.

First, it is necessary to support effective learning ability improvement by operating individualized programs for students with poor learning such as academic warnings. Currently, student support is mainly provided by a non-individual, instructor-centered approach centered on special lectures. In the future, however, programs to meet individual needs is required. Therefore, it is important to consider how to introduce the brain training program applied in this study.

Second, in order to improve the effectiveness of the brain training program, it is necessary to design the program according to the minimum medium-term plan. For example, by opening and operating at least one semester credit course for underprivileged students (selecting or compulsory liberal arts), it is possible to impose responsibility for participation in brain training programs and reduce the burden of extracurricular time administration. Through this, by providing practical and intensive diagnosis and training, it is considered to be practical help to improve students' teaching and learning ability.

Third, the brain training program should establish an integrated support system in connection with the counseling program for individual students. This is because learning outcomes are very closely related to each area of the student's personal life. It is effective and efficient in improving learning outcomes only when counseling in the area of learning counseling and in other areas is conducted in parallel.

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