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Descriptive Study of Electromagnetic Wave Distribution for Various Seating Positions: Using Digital Textbooks

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Abstract

To better understand environmental electromagnetic wave exposure during the use of digital textbooks by elementary school students, we measured numeric values of the electromagnetic fields produced by tablet personal computers (TPCs). Specifically, we examined the distribution of the electromagnetic waves for various students' seating positions in an elementary school that uses digital textbooks. Electric and magnetic fields from TPCs were measured using the HI-3603 Visual Display Terminal/ Very Low Frequency (VDT/VLF) radiation measurement system. Electromagnetic field values from TPCs measured at a student's seat and at a teacher's computer were deemed not harmful to health. However, electromagnetic field values varied based on the distance between students, other electronic devices such as a desktop computers, and student posture while using a TPC. Based on these results, it is necessary to guide students to observe proper posture and to arrange seats at an appropriate distance in the classroom.

Keywords

digital textbook, electromagnetic field, environmental, school, elementary students

The current paradigm of information and knowledge acquisition and use has brought about various novel teaching and learning methods that demand fewer temporal restrictions. Such developments have necessitated a change in the use of printed texts as a core medium of education. As a part of this development, the Korea Education and Research Information Service has developed a digital textbook format, and 132 schools used digital textbooks on a trial basis in 2010 in the Republic of Korea (Cho, 2008; Korea Education and Research Information Service KERIS, 2011). In addition, the Ministry of Education, Science, and Technology has plans to expand the use of digital textbooks in all subjects in elementary, middle, and high school by 2015 (Ministry of Educational Science and Technology MEST, 2011). Digital textbooks have the advantages of mobility, convenience, and the utilization of extensive learning resources but may also pose concerns that need to be addressed (Cho, 2008; Park, 2010). One major concern regarding digital textbook usage is the effect of electromagnetic waves from the computers used for the digital textbooks on growing children and adolescents. It is important to be aware of how electromagnetic waves affect young bodies.

Electromagnetic waves are the composite waves of the electric and the magnetic fields in the form of energy generated from the consumption of electricity. Electromagnetic waves are emitted from electronic machines and devices that are used in daily life. An electric field consists of the electric forces that are vertically charged and is described in units of volts per meter (V/m). A magnetic field consists of the magnetic forces that are horizontally charged and is most often described in units of milligauss (mG; Seo, 2000). Electromagnetic waves are classified by frequency (number of vibrations per second), the electric power frequency for domestic use (60 Hz), extremely low frequencies (0–1 kHz), low frequencies (1–300 kHz), medium frequencies (300 kHz–300 MHz), and microwaves (300 MHz–300 GHz; Hwang, 2009). The frequency of the waves increases in the order of infrared light, visible light, ultraviolet light, x-rays,

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and gamma rays. Among the frequency categories, the extremely low and the low frequencies generate the electric and the magnetic fields, respectively. The body's exposure to low-frequency and extremely low-frequency electromagnetic waves for a prolonged duration may change its temperature, break its biorhythm, and cause illness (Kim, 2011). It has been confirmed that when a strong electromagnetic wave with high frequency meets an entire or partial body, it causes an increase in the body's temperature and affects health (Hwang, 2009). This process is called the thermal effect. Similarly, the case in which a low-frequency-induced current in the body stimulates the nerves is termed the stimulating effect. Because the electric and chemical changes in the body affect nerve functions, very strong electromagnetic waves may affect the body, contributing to stress, heart disease, and chemical changes in the blood. However, there are no grounds for the notion that the effect of the low-level electromagnetic waves, to which the public is exposed to daily, is harmful to health. Although electromagnetic waves have never been proven to be harmful to health, it is thought that avoiding the sources of electromagnetic waves, whenever possible, is preferred.

The purpose of this study was to measure the electric and the magnetic fields from students' tablet personal computers (TPCs) based on Swedish Standards (Measure and Proof Radiation [MPR] Board-II; FMS, 2009; Lee, 2004) in order to better understand environmental exposure to electromagnetic waves during the use of digital textbooks. The study findings can be used to design safe and appropriate environments for the use of digital textbooks by suggesting the proper placement of TPCs. Ultimately, the study findings can help reduce concerns regarding environmental effects associated with the use of digital textbooks.

Method

Research Design

To understand the environment that is exposed to electromagnetic waves originating from the use of digital textbooks, this descriptive study measured the distribution of electromagnetic waves while students use the digital textbooks for class in an elementary school.

Ethical Consideration

This study was exempt from full review by the Institutional Review Board of Korea University because the work consisted of usual processes in the educational setting. Nevertheless, we obtained consent from the school principal and homeroom teacher of the participating school to measure the electric and the magnetic fields from the student TPCs. Research participant agreements and explanation letters for this study were sent to the students' homes and were received prior to the commencement of the study. Considering the ethical aspects of the study, the explanation letter clarified that participants would not sustain any harm during the study period and that the participants could refuse to participate if they did not wish to measure the electric and the magnetic fields produced by their TPCs.

Table 1. Electric and Magnetic Field Values per the Standards of MPR-II.

	Normal range	MPR-II (20 in.)
Electric field	VLF (2 kHz–400 kHz)	Under 2.5 V/m
Magnetic field	VLF (2 kHz–400 kHz)	Under 0.25 mG

Note. MPR-II = Measure and Proof Radiation, Board-II; VLF = very low frequency.

Research Objects and Locations

The objects of this study used for measuring electromagnetic waves were the TPCs that were used by the students for their digital textbook work in an elementary school in Seoul, South Korea. The classroom environment in which the electromagnetic wave measurements were conducted had four internal windows and eight external windows. The windows were kept shut when the electromagnetic waves were being measured. Devices that could emit electromagnetic waves in the classroom included eight fluorescent lights, a 15-in. plasma display panel (PDP) TV, an air conditioner, and two wall-mounted fans. For electromagnetic field measurements in the real-life classroom environment, all electronic devices were set up as on an ordinary day.

Electromagnetic fields were measured on July 9, 2009, from 11:00 a.m. to 2:00 p.m. At that time, all 32 students were using TPCs, and the teacher was using the teacher-specific computer. Because the students used charged TPCs, the electromagnetic fields measured were generated by the TPCs disconnected from the power supplies. The electromagnetic field of the teacher's computer was measured while the computer was connected to the power supply. While measuring electromagnetic fields, the students maintained a distance of 16 in. from the students in front of them and a distance of 20 in. from the students to their sides.

Method of the Electromagnetic Field Measurement

In order to investigate the distribution of the electromagnetic waves around the elementary school students using the digital textbooks, the electric and the magnetic fields were measured with the HI-3603 VDT/VLF radiation measurement system (A-A.co.kr, 2005). The unit for electric field measurements is volts per meter (V/m), and the unit for magnetic field measurements is milligauss (mG). Both the electric and the magnetic fields, which are formed in the air owing to the charge and the current, have vectors with values and directions; therefore, each of the forces was measured in the x-, y-, and z-axis directions for a distance of 20 in., under the standards of the MPR Board-II (Table 1).

With the students using the digital textbooks on their personal TPCs, the field strengths on the front and the rear

sides of the individual notebook computers were measured. The measurements were in consideration of the possibility that a student may be affected by the electromagnetic waves of the computer in the row behind them, for a length of 16 in., although the distance between a student and a TPC was approximately 20 in., according to the seating arrangement.

The electric and magnetic field strengths were measured, and each result was analyzed using the formula $F = \sqrt{Fx^2 + Fy^2 + Fz^2}$ (Hwang, 2009) to determine whether it exceeded the MPR Board-II criteria. The unit for the measurement of the electric field strength was V/m, which was the unit used by the HI-3603 device. The unit for the measurement of magnetic field strength was mG, where 1 mG equals 80 mA/m, and hence, the measured values were divided by 80, and the resultant calculated values were used.

Throughout the use of the digital textbooks and the electronic pen, the distance between the TPC and a student fluctuated between 20 and 8 in. This study accordingly measured the electromagnetic waves at the distance of 8 in. for three students' TPCs that showed the lowest figures at the distance of 20 in. to examine the dependence of various distances between a student and a TPC on the difference in electromagnetic waves.

Results

The distribution of electromagnetic waves per seat in a classroom using digital textbooks is illustrated in Figure 1. According to the results measured at a distance of 20 in. from the front and the rear surfaces of the electronic device, under the standard of the Swedish MPR Board-II, the highest measurements for electromagnetic waves consisted of an electric field of 0.595 V/m and a magnetic field of 0.058 mG measured in front of the teacher's computer. Among the students' TPCs, student in seat no. 1 showed the highest values, an electric field of 0.563 V/m and a magnetic field of 0.050 mG, both measured from the front side of the TPC. The lowest figures among the students' TPCs were measured at seat no. 21, an electric field of 0.231 V/m and a magnetic field of 0.017 mG. These figures were lower than the MPR Board-II standard that specified an electric field of 2.5 V/m and a magnetic field of 0.25 mG.

To examine the differences in the electromagnetic waves based on the distance between a student and his or her TPC monitor, the regions around seat nos. 18, 20, and 21, which showed the lowest field strengths at a distance of 20 in., were subjected to the electromagnetic field strength measurements at a distance of 8 in. (Table 2). The region around a student TPC that showed the lowest values, namely, an electric field of 0.260 V/m and a magnetic field of 0.022 mG at a distance of 20 in., showed an electric field of 1.149 V/m and a magnetic field of 0.136 mG at a distance of 8 in. These values were higher than the highest values recorded for seat no. 1; however, all of the measurements were lower than the electric field of 2.5 V/m and the magnetic field of 0.25 mG specified by MPR Board-II standards.

Discussion

With no previous research existing on electromagnetic wave exposure resulting from the use of digital textbooks, the findings from the current study could not be compared to other study results. We measured electromagnetic waves from TPCs in a classroom of an elementary school; therefore, the findings should be cautiously considered when generalizing to other settings, which is a limitation of this study.

However, this study suggests a meaningful method and criteria for measuring electromagnetic field strengths that may be used for comparisons in future studies. The current study may also be helpful in designing safe and appropriate environments for the use of the digital textbooks by suggesting the proper placement of TPCs. The study may also contribute to reducing unsubstantiated concerns regarding exposure to the electromagnetic waves from digital textbooks.

According to the measured results of the electromagnetic waves, the teacher's computer showed the highest values of the electromagnetic field strength in the classroom, but the figures were not at a level that is harmful to the body. The teacher's computer used a relatively complex electrical design (in the fact that it was a notebook computer connected to a power source), and, therefore, for this reason it likely showed higher values for electromagnetic field strength than the student TPCs. The teacher's computer was connected at all times to a power source unlike the student TPCs that operated on batteries with no connection to a power source. The TPC at student seat no. 1 was nearly in contact with the teacher's computer and showed the highest field strength values. In addition, student seat nos. 1 and 2, which were both close to the teacher's computer, had higher electromagnetic wave measurements than other student seat positions. Nevertheless, values of the electromagnetic field strength measured at the teacher's computer and at seat no. 1 were not harmful to health, per MPR Board-II standards. It may still be advisable that the student seats should be arranged at a proper distance from the teacher's computer in the classroom.

According to our result, electromagnetic wave measurements at 32 student seats showed that the TPCs that the students used did not generate electromagnetic field strengths at a level of concern, but that the distance from the TPCs often tended to be shorter by up to 8 in. from the guideline of 20 in. at different seats. When students closely examined the TPCs or used electronic pens, the distance from the TPC, which was to be maintained at 20 in., was reduced up to 8 in., which would accordingly increase the exposure level to electromagnetic waves. Electromagnetic field strengths measured at a distance of 8 in. tended to be higher, as expected, but were also not at a level harmful to the body.

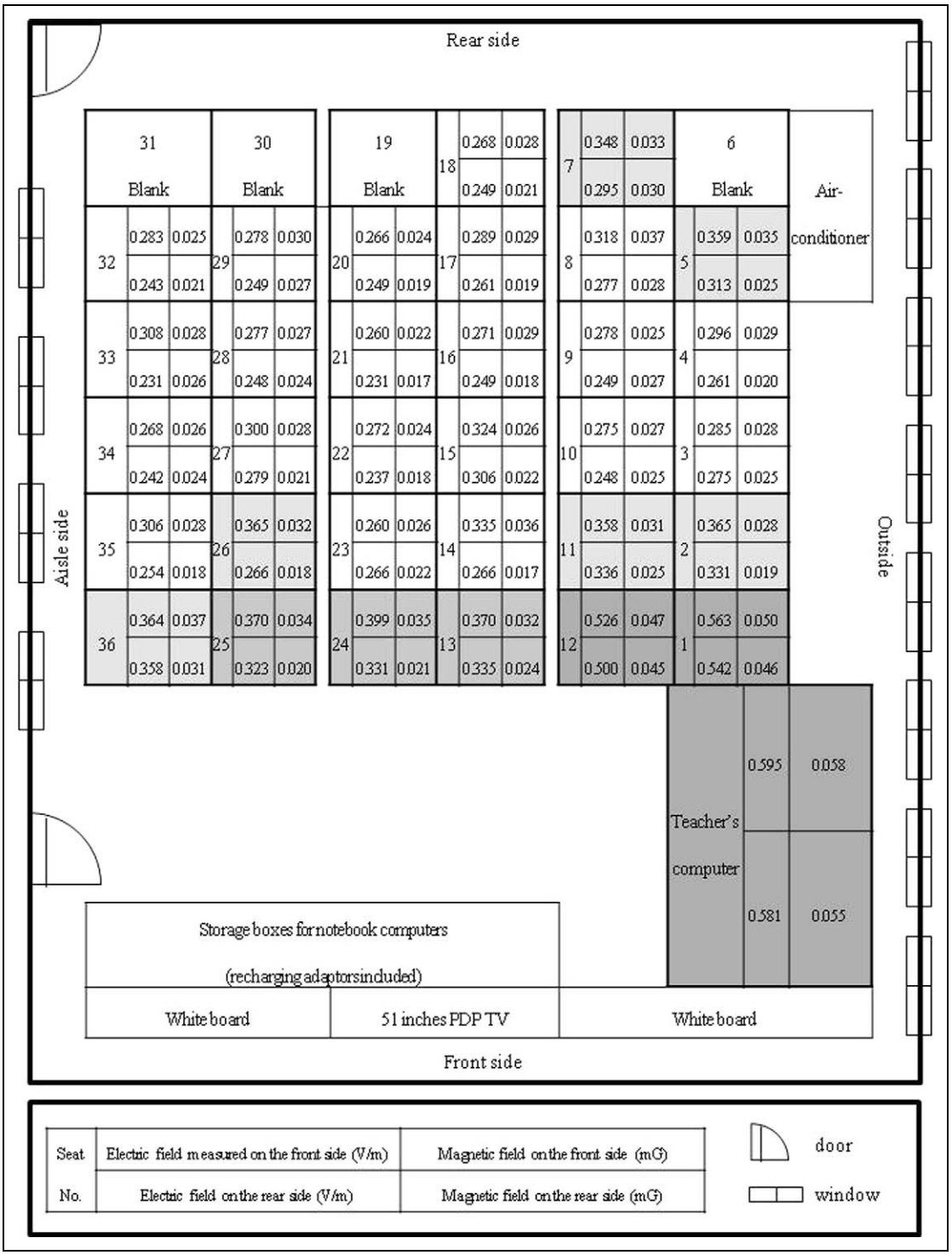

Figure 1. Distribution of the electromagnetic waves for each seat in an environment in which digital textbooks are used. It diagrams a classroom in which students use digital textbooks. The numbers in left-hand side indicate the locations of students (nos. 1–36) and a teacher computer is in the front near the white board. The distribution of electromagnetic waves is illustrated in colors. Darker gray indicates high distribution of electromagnetic waves.

Thus, electromagnetic field strengths at the students' seats were found to be at levels not harmful to health. However, with the voiced health concerns from regular users of digital textbooks on the effects of the electromagnetic waves, it is recommended that users maintain a proper distance from TPCs, as suggested.

Table 2. Difference in Electromagnetic Wave Measurements at a Distance of 8 in.

	Electric field (V/m)		Magnetic field (mG)	
Seat no.	20 in.	8 in.	20 in.	8 in.
18	0.268	1.486	0.028	0.141
20	0.266	1.255	0.024	0.135
21	0.260	1.149	0.022	0.136

The study also found that the distribution of the electromagnetic field strength per seat in the digital-textbook-use environment was affected by other electronic equipment in the classroom. Seat nos. 1, 12, 13, 24, and 25 and seat nos. 2, 5, 7, 11, 26, and 36 showed higher electromagnetic field strengths (with varied values) than other positions. These may have been influenced by the PDP TV and the air conditioner in the classroom. As all electronic products are sold in compliance with the electromagnetic standards in the Republic of Korea, they are deemed not to pose problems in this regard. As seen in this study, the sum of the figures rather than the individual figures is thought to be of relevance. Although it is not certain as to why seat nos. 1, 12, 13, 24, and 25 showed higher values for electromagnetic field strength, we may assume that these were a result of other electronic devices in the space.

In current digital-textbook-use environments, electromagnetic field strength values in the classroom were not a concern at the current levels (per MPR Board-II standards). However, the distance between the student seats, the distance between the electronic devices, and the distance of students from the TPCs, as determined by the computer usage posture, affected the measured magnetic field strength. The results point to the recommendation that seats should be placed at a proper distance from each other and from other electronic devices when digital textbooks are used. The results also show that students need to learn to maintain proper posture in the classroom when using digital textbooks, as different body postures differentially affected the experienced electromagnetic field strength.

Conclusion

With the increased usage of digital textbooks, there have been questions raised regarding the effects of electromagnetic wave exposure from computers used by growing children. Thus, this study measured the electric fields and the magnetic fields of TPCs used for student digital textbooks, according to MPR Board-II standards in a classroom, in order to understand the distribution of the electromagnetic field strength. The objects of this study were student TPCs in the sixth grade of an elementary school in Seoul where digital textbooks were being used. The results of this study showed that electromagnetic field strength values measured at all 32 student seats and at the teacher seat were not at levels harmful to health. Additional values measured at a distance of 8 in. were also not found to be at levels harmful to health. Although a distance of 20 in. is recommended by the standards of the MPR Board-II, the actual distance between one student and another in the front or rear was 16 in. Furthermore, the effects of electromagnetic waves generated from a TPC used by a student in the next row may not be ignored. It is recommended that seats should be placed such that the distance between the student seats is more than 20 in. in a classroom in which the digital textbooks are used.

Implications for School Nursing

In South Korea, the Ministry of Education, Science, and Technology plans to expand the use of digital textbooks in all subjects in elementary, middle, and high schools by 2015. Digital textbooks have many advantages as educational materials, but many people are concerned regarding electromagnetic effects on the health of people using digital textbooks. Following the results of this study, the electromagnetic field values measured at student seats and at a teacher's computer were not harmful to health. However, the distance between student seats, electronic devices, and the TPCs, depending on the student's posture while using the TPC, affected electromagnetic field values. These results can be used as the basis for school nurses who have the responsibility of caring for students and extend to scholars in other countries where digital textbooks are used. The results of this study may also be helpful in designing safe and appropriate environments for the use of the digital textbooks by suggesting the proper placement of TPCs.

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