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GyeongAe Seomun, Wonjung Noh
Republic of Korea

Development of a Tool for Measuring Adverse Health Effects Due to Digital Textbook Use

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Abstract

This study developed a tool for measuring adverse health effects in students who use digital textbooks. The study tool was aimed at 690 sixth-graders who had used digital textbooks for more than a year in schools taking part in the nationwide digital textbook pilot program. We determined the validity and reliability of the tool. The tool for measuring adverse health effects of digital textbooks consisted of a total of 22 items, including 13 on physical symptoms and 10 on psychological symptoms. For the physical symptoms, two factors – whole body/musculoskeletal symptoms and eye symptoms – were extracted. For the psychological symptoms, the two assessed factors included negative and positive psychological symptoms. This tool will not only be helpful in preventing and managing adverse health effects of digital textbook use by identifying various physical and psychological symptoms, but will also be useful as a basis for the expansion of digital textbooks.

Keywords: *adverse effects, digital textbook, health, measure, tool*

Introduction

South Korea has developed digital textbooks for schools so that teaching and learning activities can be carried out anywhere, keeping up with the trends of the twenty-first century society, in which easy access to information and knowledge is particularly valued (Korea Education and Research Information Service, 2011).

Digital textbooks had been planned to be distributed to all students in elementary, middle, and high schools by 2015 (Ministry of Educational Science & Technology, 2011). Learning with the use of digital devices is being implemented not only in Korea, but also in many countries, from elementary school students to college students (Czerniewicz & Brown, 2014). Expanding the use of digital devices in many countries can help to provide education without time and space constraints, which can reduce regional disparities such as between cities and rural areas. Therefore, countries with a larger area can extend the benefits of learning from digital devices more than others.

Digital textbooks, however, have some health-related issues. Seomun, Kim, and Noh (2012) pointed out that there are a number of physical and psychological health issues that arise in students who use digital textbooks during their adolescence, which is a period of rapid physical and psychological growth. These health issues must be considered, despite the considerable benefits of digital textbooks (Seomun, Kim & Noh, 2012).

To examine the physical and psychological health issues of students who use digital textbooks, there is a need for an appropriate measuring tool. Expanding digital textbook use will result in considerable changes to the traditional classroom teaching and learning style throughout all school levels, and these changes might significantly affect student health. However, there is currently no appropriate tool for assessing digital textbook – health correlations. Although a similar measure, the visual display terminal (VDT) syndrome tool, is used to examine the health of people who use computers extensively in their occupational lives, it is not appropriate for assessing the effect of digital textbook use on students.

Therefore, we developed a tool for measuring the adverse health effects of digital textbooks so that we might better understand these effects in students. The tool was based not only on students' subjective opinions, but also on the opinions of teachers and experts.

Purpose

This was a methodological study for developing a tool to measure potential adverse health effects of digital textbook use on students. After pooling the items and devising the tool, we examined its validity and reliability.

Research Methodology

Participants

The subjects were 690 female and male sixth-graders who had used digital textbooks for over a year at Korean schools taking part in the nationwide digital textbook pilot program. All the subjects' parents provided written informed consent. Among the subjects, 342 (49.6%) were males and 348 (50.4%) were females. Five hundred and fifty students (79.7%) used computers at home, 225 (32.6%) had spent more than 3 hours communicating with their family each week, 256 (37.1%) took breaks from Internet use at least every hour, and 350 (50.7%) reported middle-level grades. Regarding school life satisfaction, the majority of the students (426; 61.7%) replied that they were "satisfied" (Table 1).

Table 1. General characteristics of study participants (N=690)

Characteristics	Categories	N (%)
Gender	Male	342 (49.6)
	Female	348 (50.4)
Location of computer use	School	71 (10.3)
	Internet cafe	24 (3.5)
	Home	550 (79.7)
	Other	45 (6.5)
Communication time with family per week	Lower 30 min	52 (7.5)
	30 min ~ 1 hr	131 (19.0)
	1hr ~ 2 hrs	166 (24.1)
	2 hrs ~ 3 hrs	116 (16.8)
	Upper 3 hrs	225 (32.6)
Rest frequency while using the Internet	Every 30 min	213 (30.9)
	Every 1 hr	256 (37.1)
	Every 2 hr	63 (9.1)
	Every 3 hr	21 (3.0)
	Never	137 (19.9)
School record	Upper	232 (33.6)
	Middle	350 (50.7)
	Lower	108 (15.6)
Satisfaction with school life	High	426 (61.7)
	Middle	211 (30.6)
	Low	53 (7.7)

Procedure

To develop a tool for measuring adverse health effects of digital textbooks, we reviewed the related literature and conducted in-depth interviews with the students and focus-group interviews with teachers and experts. We additionally conducted objective examinations of the students who used digital textbooks, including the evaluation of dry eye syndrome and carpal tunnel syndrome and administering brain activity tests. According to the results of the examinations, literature review, interviews, and focus groups, we created a preliminary questionnaire to measure adverse health effects of digital textbook use on students (Seomun et al., 2009). This preliminary questionnaire consisted of 21 physical symptom items and 24 psychological symptom items. The secondary tool consisted of 12 physical symptom items and 10 psychological symptom items. The items were rated on a 4-point scale, as follows: 1 (not at all), 2 (sometimes), 3 (often), and 4 (always). Higher scores indicated more severe adverse health effects.

For data collection, approval was obtained from the principals and teachers in charge of the subjects' schools, and letters explaining the questionnaire and participation consent forms were sent out to the parents and collected. We explained that the participants could withdraw from the study at any time if they wished and that the collected data would be anonymous and used for research purposes only.

Data Analysis

The data were analysed with the use of SAS 9.2 statistical analysis software (SAS Institute, Inc., Cary, NC, USA) and IBM SPSS Amos 21.0.0 statistical analysis software (Amos Development Corporation). General subject characteristics were analysed using descriptive statistical methods. Construct validity was determined through item analysis, principle component analysis using a varimax rotation, and confirmatory factor analysis. Construct reliability was determined using the split-half technique and Cronbach's α coefficient, which is a measure of internal consistency.

Research Results

Validation verification

We determined the validity of the tool by conducting factor analysis. First, we performed the Kaiser-Meyer-Olkin (KMO) measure, which examines the validity of a sample toward the entire population by comparing the size of the simple correlation coefficient and the partial correlation coefficient to assess the fitness of

the data for factor analysis. If the KMO value is under 0.50, it is considered inappropriate for factor analysis. However, if it is 0.80 or above, the data are considered to be suitable for factor analysis. The KMO values were 0.956, indicating that the data were suitable for factor analyses.

Additionally, the significance value was <0.001 for both the physical and psychological symptoms according to Bartlett's test of sphericity ($\chi 2 = 13735.016$, $P = .048$). If the sphericity test significance value is >0.05, then the sample size compared to the number of questions is considered inappropriate. Thus, the sample size in this study was appropriate.

For the factor extraction model, we conducted a series of exploratory factor analyses to determine the number and essence of each potential factor. The factor analysis method used was the principle component analysis, which can predict and minimise data loss by extracting the minimum number of factors. The factor rotation used was a varimax rotation.

According to the results of the primary factor analysis, items that had factor loadings above the minimum of 0.40 and did not have high overlap loadings with other factors were selected to distinguish each factor.

In the physical symptoms, items that disagreed with the overall makeup of Factor 1, and items that had a high overlap loadings with Factor 2, including numbers 1 ("I yawn when I use digital textbooks"), 2 ("I become tired when I use digital textbooks"), 6 ("I get discomfort or stiffness in the neck when I use digital textbooks"), 9 ("I get a headache when I use digital textbooks"), and 10 ("I feel nauseous when I use digital textbooks") were removed. Questions that disagreed with the makeup of Factor 2 and those that had high overlap loadings with Factor 1, including numbers 4 ("The writing looks blurry when I use digital textbooks"), 13 ("I get bloodshot eyes when I use digital textbooks"), 18 ("I feel discomfort in my eyes when I use digital textbooks"), and 21 ("I get spasms around the eyes or twitching in the eyelids when I use digital textbooks") were removed. Through this factor extraction process, 12 items in 2 factors were selected from the total of 21 items after removing 9 items from the physical symptoms. Factor 1 consisted of physical symptoms affecting the whole body and musculoskeletal system; the eigenvalue was 4.370, the accumulative variance was 54.623%, and the factor loading for each item ranged from 0.597 to 0.816. Factor 2 consisted of eye symptoms; the eigenvalue was 3.384, the accumulative variance was 26.404%, and the factor loadings for the items ranged from 0.690 to 0.811.

For the psychological symptoms, items that had high overlap loadings with Factors 3 and 4, including numbers 4 ("I feel confused because digital textbooks

have too many functions"), 7 ("I become impatient when I use digital textbooks"), 9 ("I do not feel like moving even during break after using digital textbooks"), and 23 ("I get competitive when my friend next to me goes faster than I do when using digital textbooks"), were first removed. In addition, we removed numbers: 5 ("I do not look at other websites when using digital textbooks"), 10 ("Sometimes I do something other than study when using digital textbooks"), 12 ("I become more cautious in my behaviour when I use digital textbooks"), 13 ("Conversation time with friends decreases when I study with digital textbooks"), 15 ("I think digital textbooks are more efficient than paper textbooks for studying"), 17 ("I feel the urge to destroy the digital textbook when it does not work in the way I want it to"), 19 ("I have ruined the digital textbook at some point because I become irritated"), 21 ("I sometimes do not realise somebody is calling me because I become absorbed in the digital textbook"), 22 ("I am not interested in using the Internet at home on days when I use digital textbooks"), and 24 ("My concentration drops when I study with digital textbooks due to their various functions compared with paper textbooks") because their factor loadings were <0.40 and their overlap loadings were high with other factors.

Thus, through this factor extraction process, we selected 10 items in 2 factors by removing 14 items from the initial 24 for psychological symptoms. In the psychological symptoms, Factor 3 included negative psychological symptoms; the eigenvalue was 3.416, the accumulative variance was 48.805%, and the factor loadings for each question ranged from 0.633 to 0.744. Factor 4 included positive psychological symptoms; the eigenvalue was 2.452, the accumulative variance was 29.035%, and the factor loading for the questions ranged from 0.624 to 0.752 (Table 2).

Finally, we conducted confirmatory factor analysis to test goodness of fit to determine the 4-factor measurement model: $\chi 2$, the Goodness of Fit Index (GFI), the Adjusted Goodness of Fit Index (AGFI), the Root Mean Square Error of Approximation (RMSEA), the Tucker-Lewis Index (TLI), the Normed Fit Index (NFI), the Comparative Fit Index (CFI), and the Root Mean Square Residual (RMR). The 4-factor measurement model of the 22 items indicated a good fit for the instrument according to the fit indices (AGFI = 0.917, RMSEA = 0.049, NFI = 0.901, and RMR = 0.041). The factor loadings for the 22 items ranged from 0.597 to 0.816 (Figure 1).

Table 2. Factor analysis

Factor		Item	Mean (SD)	Factor loading	Eigen Values	Accumulative Variance (%)
Physical symptoms	Factor 1 Whole body and musculoskeletal symptoms	5. My fingers begin to feel numb when I use digital textbooks.	1.41 (0.83)	0.597	4.370	54.623
		11. My wrist hurts or goes to sleep when I use digital textbooks.	1.47 (0.81)	0.683		
		15. I feel pressure in my chest when I use digital textbooks.	1.49 (0.91)	0.724		
		16. I feel dizzy when I use digital textbooks.	1.62 (1.00)	0.767		
		17. I feel discomfort or pain in my shoulders when I use digital textbooks.	1.71 (1.00)	0.816		
		19. I feel discomfort or pain in my back when I use digital textbooks.	1.65 (0.99)	0.790		
		20. I think my physical strength decreases when I use digital textbooks.	1.55 (0.92)	0.756		
	Factor 2 Eye symptoms	3. My eyes become dry when I use digital textbooks.	2.01 (2.15)	0.747	3.384	26.404
		7. My vision gets worse when I use digital textbooks.	1.88 (1.00)	0.726		
		8. My eyes sting and hurt when I use digital textbooks.	1.68 (0.94)	0.811		
		12. My eyes become tired when I use digital textbooks.	1.98 (0.99)	0.798		
		14. My eyes get teary when I use digital textbooks.	1.45 (0.83)	0.690		

Factor		Item	Mean (SD)	Factor loading	Eigen Values	Accumulative Variance (%)
Psychological symptoms	Factor 3: Negative psychological symptoms	1. I become impatient when there is a problem with the digital textbook.	1.75 (0.87)	0.656	3.416	48.805
		2. I become forgetful of what I should do when I use digital textbooks.	1.54 (0.81)	0.712		
		6. I become bored of repeatedly using the same functions on digital textbooks.	1.85 (0.97)	0.702		
		8. I become irritated when the digital textbook does not work.	2.41 (1.21)	0.633		
		11. I become stressed that the class does not go well with digital textbook use.	1.83 (1.04)	0.721		
		14. I become tired more easily when I study with digital textbooks than with paper textbooks.	2.02 (1.09)	0.744		
	Factor 4: Positive psychological symptoms	3. I become more interested in studying when digital textbooks are used in class.	2.10 (0.91)	0.624	2.452	29.035
		16. I can concentrate better with digital textbooks than with paper textbooks.	1.86 (1.12)	0.752		
		18. I feel confident during classroom presentations because of using digital textbooks.	1.70 (0.92)	0.676		
		20. I think using digital textbooks helps with understanding the course contents.	1.99 (1.01)	0.705		

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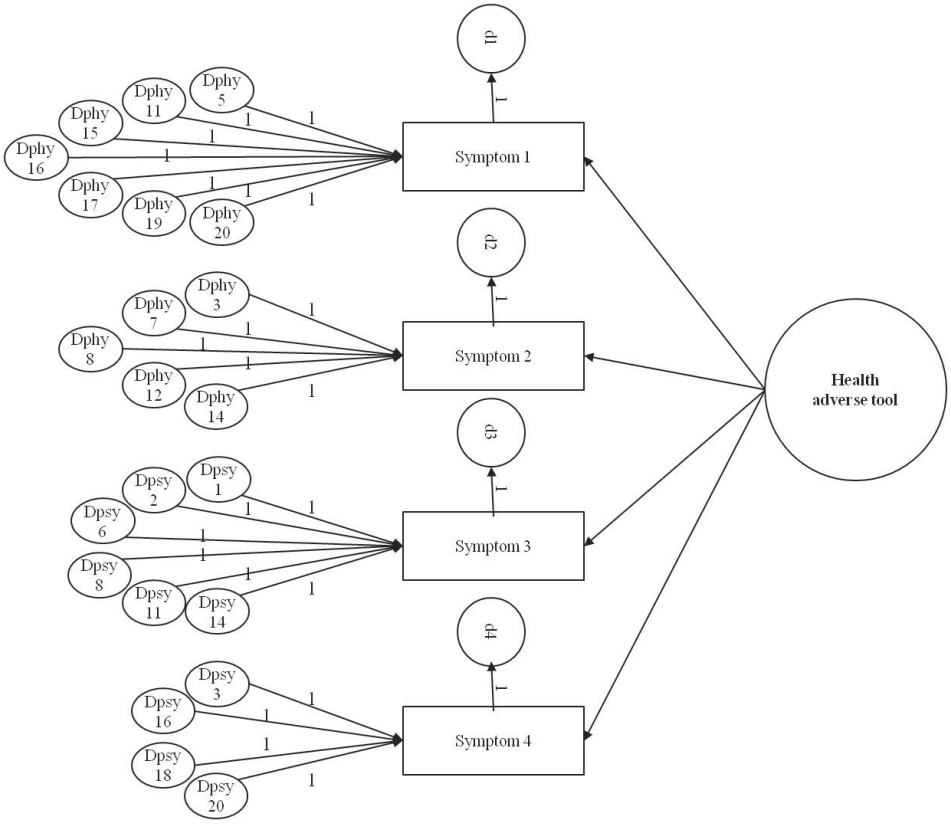

Figure 1. Confirmatory factor analysis

Reliability verification

According to the results using the split-half technique, the reliability of odd number items was 0.888. The odd number items were 0.859 for physical symptoms and 0.815 for psychological symptoms.

Cronbach's α, which is a measure of internal consistency, of the final 4 factors and 22 items was 0.915. It was 0.921 for physical symptoms and 0.790 for psychological symptoms. Among the physical symptoms, the factor "whole body and musculoskeletal symptoms" had the highest value at 0.881, followed by "eye symptoms" at 0.851, "negative psychological symptoms" at 0.849, and "positive psychological symptoms" at 0.769.

Discussion

In this study, we conducted literature reviews and in-depth interviews with students and focus-group interviews with teachers and experts to develop tools. These research methods are appropriate because previous researchers also developed and validated tools based on student, teacher, and expert focus group interviews when developing tools to measure student-related variables (Matorera and Fraser, 2016). Our analysis revealed that the 22 items in this adverse health effect tool were appropriate by using confirmatory factor analysis to test goodness of fit to validate the 4-factor measurement model. The recommendations for a good fit were the following: $\chi 2$'s P values greater than 0.05, GFI/AGFI/TLI/NFI/CFI values greater than 0.90, and RMSEA/RMR values under 0.05 (Seomun et al., 2009). This tool indicated a good fit for our instrument according to the fit indices.

Two factors were extracted for physical symptoms: "whole body and musculoskeletal symptoms" and "eye symptoms." These factors explained 81.027% of the variance. Furthermore, 2 factors were extracted for psychological symptoms: "negative psychological symptoms" and "positive psychological symptoms," which explained 77.840% of the variance.

There were 7 items in the "whole body and musculoskeletal symptoms" factor, all based on the results of the literature review, interviews, focus-group interviews, and carpal tunnel syndrome tests. The musculoskeletal symptoms appeared to manifest across the entire body, and the correlations among these symptoms appeared high, i.e., they often co-occurred. Therefore, we assumed that the body and musculoskeletal system could not be separated and they showed roughly the same properties. Thus, we grouped them together. Whole body and musculoskeletal symptoms frequently occur in elementary students who use computers for long periods. In previous studies of the relationship between Internet addiction and VDT syndrome in elementary students, musculoskeletal pain and tiredness increased significantly according to the degree of Internet addiction, indicating that it occurs in students who use computers for long periods (Lee, Hwang, 2008).

The "eye symptoms" factor contained 5 items. According to the various interviews and preliminary examinations, which included dry eye syndrome tests, the students mainly complained about dryness or tiredness in their eyes, indicating that it was appropriate to extract these items. Moreover, in a study of VDT-related self-recognised symptoms in teenagers, eye symptoms were the second most frequently reported symptoms, after musculoskeletal symptoms. Thus, the extraction of this factor was appropriate (Lim, Kam, Han, Kang, and Cha, 2002).

There were 6 items in the "negative psychological symptoms" factor. The interviewed students reported being stressed due to program errors or Internet speed, and therefore the extraction of these items was deemed appropriate. The mental and psychological stress related to computer use also appeared in the study by Kim and Cho, which showed that people with computer addiction and high computer usage had more mental symptoms than whole body, musculoskeletal symptoms, or eye symptoms (Kim and Cho, 2005).

Finally, there were 4 items in "positive psychological symptoms." This agreed with the results of Suh, Seo, and Hwang (2009), showing that using digital textbooks promotes learning activities that traditional paper textbooks do not allow and increases problem-solving ability (Suh, Seo, and Hwang, 2009). This helps students to be more interested in learning and concentrate on their studies and improves their studying efficiency by increasing their understanding of the content. These findings were also clear from the results of the interviews, indicating that our extracted items were appropriate.

According to the results of the split-half method, the odd number items were 0.888, the values for the physical symptoms were 0.859, and the values for the psychological symptoms were 0.815. Cronbach's α of the final 22 items was 0.907: of this, Cronbach's α for the physical symptoms was 0.867 and for the psychological symptoms was 0.819. Because the participants were primarily elementary school students and thus were very active, Cronbach's α of the physical symptoms appeared higher than that of the psychological symptoms.

Implication

Thus far, many studies on the effect of digital devices on students' learning have been performed (Hardman, 2005). However, studies on health effects have rarely been conducted with adequate measurement tools. In this study, we developed a tool with high validity and reliability by incorporating the opinions of students, teachers, and experts, as well as the results of objective examinations. Developing a valid and reliable tool that can measure adverse health effects is useful for long-term follow-up studies examining the physical and psychological symptoms associated with digital textbooks. Furthermore, this tool can help manage the symptoms of groups at high risk for such effects and add to the development of "healthier" digital textbooks. The use of healthier digital textbooks will expand the application of digital textbooks and reduce the education gap among regions.

Conclusions

We developed a tool for measuring the adverse health effects of digital textbooks to identify the most common negative effects of using digital textbooks. In the item selection, we considered the subjective opinions of the students who used the digital textbooks as well as those of teachers and experts. The construct validity was examined through item and factor analyses, and reliability was determined using the split-half method and Cronbach's α. This tool has high validity and reliability, allowing it to be effectively used to assess the adverse health effects that can occur in students who use digital textbooks.

Because digital textbook learning can minimise the gap of time and space, if we can resolve concerns about the adverse health effects caused by digital textbooks, it can be more secure in expanding education. The adverse health effects measurement tool developed in this study can be used to reduce these concerns through the assessment of adverse health effects. In addition, we suggest conducting a study in the future on middle and high school students, in addition to elementary students, to evaluate potential grade and/or age effects of digital textbook use on student health. An intervention study would be helpful for developing ways to prevent and manage the adverse health effects that we observed in this study.

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