Scientific Units Found in School Textbooks and Everyday Life

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Abstract

In this research, we surveyed how scientific units are used in textbooks and everyday contexts and also if there is any discordance between the learning of the units and the using of them in everyday life. We found out that even if the units are something regularly contacted with in everyday life, they are often learned later in the textbooks. The textbooks presented only examples of a small part of the units used in everyday contexts. On the other side, we could find a variety of units in everyday contexts. For example, distance, time, electricity, temperatures, and speed units are used in the streets, while volume and weight units in grocery shops and electricity-related, computer-related, and pressure units at home. Inscription regulations of the SI Units are well followed in the textbook, but even the basic inscription regulations are often not kept in everyday contexts. Also, Non-SI units are presented in the textbook in an introducing way and still Non-SI units were used in everyday contexts. Students were confused about scientific units with unscientific units, and units with non-units. This seems to be not only because the students do not have proper understanding over the characteristics of units, but also unscientific units are mingled and used with scientific units in everyday contexts. In conclusion, it seems that the discordance between scientific units in textbooks and units used in everyday life would cause considerable difficulty for students to use units as basic tools for scientific communication.

Keywords: Scientific units, Textbooks, Students' activity, Everyday contexts.

1. Introduction

Science is a subject of explaining the phenomena of nature though studying relationships between physical quantities. Each physical quantity is regulated into sizes and dimensions by units. The unit is the basic in explaining phenomena of nature scientifically. To scientists, units are the basic promise and communication tool.

Units are also often used in everyday contexts. Units are used when you say things like, 'by what time you have to get to work or school', 'how much the gasoline price has gone up per liter', 'how much calories you have to eat in order to lose a certain kilograms of weight.' Units are used to communicate scientifically and properly in everyday life.

Meanwhile, because the way a student gets to know about units are usually through the textbook or everyday contexts, we can compare and analyze the units in the two ways and interpret the results from the perspectives of science communication. According to a survey about the science textbook, a vast majority of the teachers (89.9%) and of the students (85.4%) said that they depend on textbooks in teaching and learning science[1].

2. Researching Process and Methods

2.1 Textbook analysis

The analysis of textbooks was done with science, math, and technology textbooks due to their close relations with units. While for elementary textbooks we used the only textbook authorized by the Ministry of Education and Human Resources Development, for junior-high textbooks we chose the textbooks which are widely used and published by the same 'K' publishing company. The textbook analysis is divided by 4 major parts(unit learning, scientific units in everyday contexts, following the inscription regulation, and presenting Non-SI units). The 'unit learning' part is the analysis of 'in what grade a student starts learning certain units'. We regulated 'unit learning' when the students learn unit-understanding factors (i.e. unit's name, symbol, definition and transformation) presented in a preceding research[2]. The 'scientific units in everyday contexts' part is to analyze how many examples of units used in everyday contexts are presented in the textbook. We decided to use examples of everyday units as the standard of the analysis, because the science subject works as a bridge that connects the real world and the scientific world. Lastly, since units are tools of communication, if the inscriptions of units are not standardized, there might be frustration when communicating. So, we checked how well the inscription regulations were being kept in the textbooks. We used the International System of Units 7th ed. 1988[3], the National Standard Fundamental Law which was enforced in 2000[4], and International Standard ISO 31[5] as the standard of the inscription regulation. Introducing Cuk-guwan-bubb(the traditional unit system of Korea) or the yard-pound system of measurement in the textbook has some positive aspects of connecting the subject with real life. Nevertheless, the National Standard Fundamental Law enforce in 2000 was established to 'improve science technology and the infrastructure of industries and to hasten the information society to

improve the nation's competitiveness'. Therefore Non-SI units need to be avoided from textbooks. In this research, 'Non-SI units accepted for use with the International System'[3] are treated as SI units.

2.2 Activities to Find Scientific Units in Everyday Life

'Activities to find scientific units in everyday life' is to find examples of units used in everyday life. The activities were introduced to give students understanding that science is not far apart from everyday life and is an useful subject in life. In this research, in finding the scientific units, the first activity was done by two 9^{th} grade students who live in Seoul. The date of the activity was August 14th and 28th 2005 and was done at the participant's home and areas near home. In the activity, we did not put boundaries in scientific units and left the participants to take pictures of units by themselves. The second activity was done by 2 classes of 7^{th} graders in Seoul. The method was same to the first activity. However, to the students request, we allowed 2~3 people to work in a group. The time period was from October 18^{th} to 24^{th}, 2005. We analyzed the students understanding in units after they handed in their reports.

3. The Contents of Scientific Units in the Textbooks

3.1 Learning units

Firstly, time units (years, months, days, hours, and minutes) and length units (center-meters and meters) etc. are taught in 2^{nd} grade math classes. The units of temperatures (°C) are taught in 3^{rd} grade science classes. The units of volume (L, mL) are taught in 3^{rd} grade math, while cm^3, m^3 are taught in 6^{th} grade math classes. The units of areas (m^2, km^2) are taught in 5^{th} grade math classes. Also, the unit of mass (or weights) (kg) are taught in 4^{th} grade math.

Students learne the general idea of the unit of speed (speed per hour) in 5^{th} grade science class and again in details in 8^{th} grade science. The unit of force (N) are taught in 7^{th} grade science classes, while the unit of energy (J) in 9^{th} grade science. Moreover, the units of electricity (V, Ω, A) in 8^{th} grade science and W in 9^{th} grade science are taught .

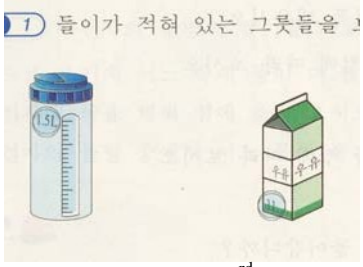
Table 1. Learning of Units according to Grade and Subject

Grade		Textbooks		
		Science	Mathematics	Technology
Elementary	1			
	2		year, month, week, day, hour, minute, cm, m	
	3	°C	mm, km, L, mL	
	4		°, second, kg, g	
	5	speed concept(no units)	m^2, km^2, ha, a, t	
	6		cm^3, m^3, %	
Middle	7	N, kgf, Hz, %(concentration),‰, pressure concept(no units)	%(concentration)	
	6	m/s, km/h, A, V, Ω, g/cm(density)		
	9	J,W(power, electric power), Wh, %(humidity),		Hz, V, A, Ω, W, Wh, lx, lm
High	10			

3.2 Scientific Units in Everyday Life

We checked scientific units used in real life that were presented in the textbook. In 10^{th} grade science textbook, as you can see in Figure 1(a), units of voltage and electric power shown with a hair dryer are presented. Besides of these, electric units used in batteries, sockets, and fuse box etc. and weight units used in scales are presented in the science textbook. In the math textbook, as you can see in Figure 1(b), the volume unit L is presented. In the math textbook, units of everyday life were presented 17 times in total. They are mainly weight or volume units. In technology textbooks, scientific units appeared about 6 times, largely related to electricity. In general, textbooks did not present many scientific units used in everyday life. Furthermore, science textbooks only present about 10 examples about scientific units used in everyday life, which is less than math textbooks.

(a) Science (10^{th} grade)



(b) Mathematics (3^{rd} grade)

(c) Technology (9^{th} grade)

Figure 1. Examples of Scientific Units of Everyday Life Appeared in Textbooks

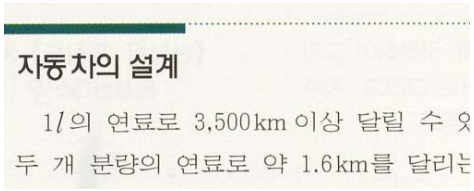
3.3 Following Inscription Regulations

According to the International System of Units 7th ed. [3] and the National Standard Fundamental Law[4], there is a regulation that says 'symbols of units are to be regularly(?) presented in small(?) Roman letters'. As you can see in Figure 2(a) in 7th grade technology textbook the size unit is written cursively (ℓ). In this case, to follow the regulation 'l and L are to be used for litter units,' 'ℓ' must be changed into 'l' or capital letter 'L'.

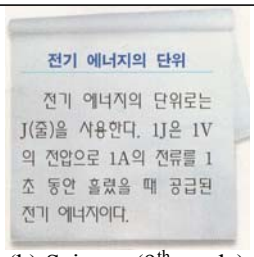
It also violated the regulation of 'numbers can be written 3 positional notations at a time in order to read comfortably, but full stops or comas can not be used between each number'. For example, '3,500' used in the textbook should be corrected to '3500' or '3 500'.

According to ISO 31 [5] it is regulated that 'Numerical value and unit symbol are separated by a space. This rule also applies to the symbol "°C" for degrees Celsius, as in "25 °C". The only exceptions are the symbols for the units of plane angle degree, minute and second, which follow the numerical value without a space in-between (for example "30°").' However, this regulation was the only one frequently ignored in the textbooks.

Compared with the result of a previous research about 20 years ago where reported many cases of violating the inscription regulations in textbooks [6], today's textbooks appear to follow the regulations quite well.



(a) Technology (7th grade)

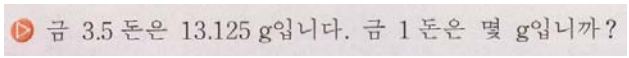


(b) Science (9th grade)

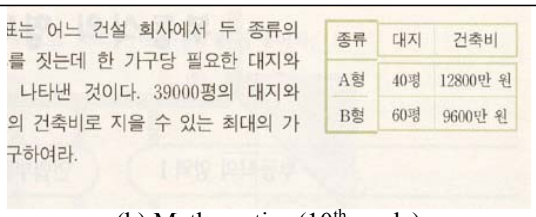
Figure 2. Examples of Violating SI Inscription Regulations

3.4 Presentation of Non-SI Units

As you can see in Figure 3(a), through the analysis of the cases of Non-SI units presented in the textbooks, 6th grade math textbooks used a traditional unit called 'don(3.75 g)'. Besides this, traditional units like 'peoung(3.3 m^2)', 'majigi(200 peoungs of rice field)' and foreign units like 'inch(2.54 cm)', 'feet(30.5 cm)' are used as well. In science textbook for 10th grade, some traditional Korean units (e.g. ja , ci, and pune) are briefly introduced. The cases that use these kinds of Non-SI units appeared about 10 times. This is a lot less compared to the preceding research[6].



(a) Mathematics (6th grade)



(b) Mathematics (10th grade)

Figure 3. Examples of Non-SI Units in Textbooks

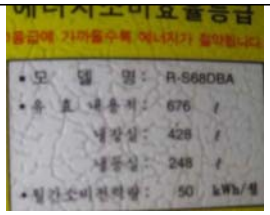
4. Units in Everyday Life and Students' Understanding of Scientific Units

4.1 Units in everyday life

Searching for units in everyday life was carried out to check how they are used in living habitats. We divided units in everyday life into those in street, in grocery store, and in home. Firstly, as you can see in Figure 4(a), the unit you can see on the streets was m written on road signs. Also, we could find time units (day and hour) on banners that are hanged on the street. We also could find weight, volume, speed, temperature units as well. As you can see in Figure 4(b), we found g on the box of instant ramen and ml on milk bottles in grocery stores. The most easily seen units at home were electric and computer based units. Since most homes have various home appliances like refrigerators, electric units (like Wh, W, and V) were easily seen. On the computer's monitors we found MB and GB. In brief, it was easy to find mechanics-related units in the streets and grocery stores while electricity-related and computer-related units at home.

(a) Scientific units on the street (m, hour)

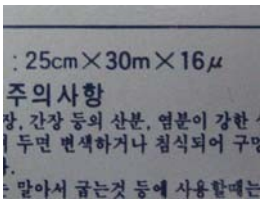
(b) Scientific units in grocery shops (g, ml)



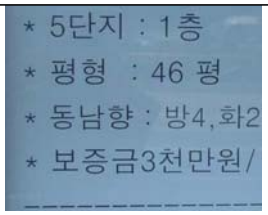
(c) Scientific units in home (V, MB)

Figure 4. Examples of the Units Found in Everyday Life

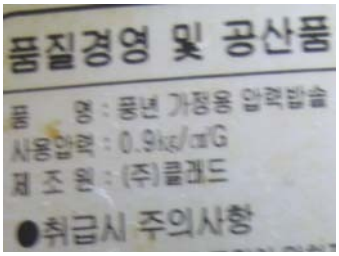
Figure 5(a) is showing the cases of presenting units incorrectly. We found a sign that had a unit of range written on it which was written (M) when it should be written (m) and a manual which deleted the unit and only presented a prefix 'μ-.' Besides that, there were cases of writing a prefix 'k-' in capital 'K' and l which is a unit of volume was written in cursive writing. There were very few cases of units written a space after numbers. Figure 5. (b) shows an example of a Non-SI unit being used. The traditional units which represent area 'peoung' and weight 'guen' are still used even though 5 years have past since the National Standard Fundamental Law enforced. We also could find Non-SI units like cc(cubic centimeter) and inch. Figure 5. (c) shows, though it is not a SI unit, used mainly in the corresponding industry area. The picture of the manual of a pressure rice cooking pot shows an example. The pressure unit is written 'kg/cm^{2}G'(this unit can also be found on outside water pipes). The student who found this was very surprised and said that, though the inscription was a bit weird, he got to know that what he learned at school was actually used in real life.



(a) Incorrect Inscription



(b) Non-SI units



(c) Special Unit for Industrial Goods

Figure 5. Cases of Units in Everyday Life Other Than SI Units

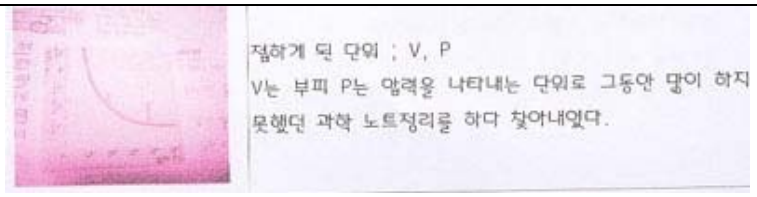
4.2 Students' Understanding of Scientific Units

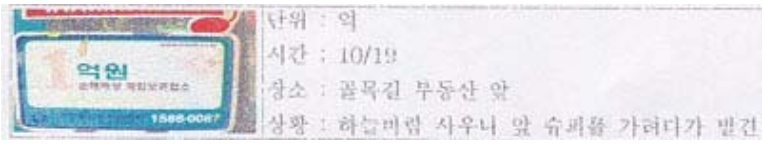
We carried out an activity of finding scientific units in real life with 67 middle school students and after the activity there were 58 reports handed in. The followings are the understanding of scientific units shown though the reports. As you can see in Figure 6(a), some students considered V and P as the units of volume and pressure respectively. It has been reported, through some preceding researches, that students confuse symbols of certain physical quantity symbols with their units [2,7]. Also, some students thought that prefixes were units, for example, they thought 'uk (; a Korean prefix same to one thousand million)' was a unit. Besides these, some students thought that 'morning' and 'dawn' were units too. Some students also thought that the size of paper 'A4' and the size of a object 'dae(large)' as units. In addition, some students thought the scientific word 'latitude' and a sort of number 'π' were units as well. Students wrote on their reports that they are confused about what are units and what are not.

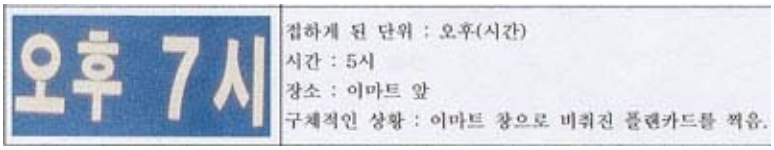
Ju-koung : I was confused that if Won, Jjock, Jang, Mari were units too. (Each of them correspond to the counting unit for Korean money, page, sheet, animal respectively)

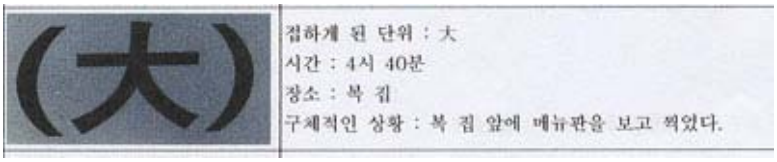
U-rea : I was surprised to find out how disinterested I was before I started to take pictures and could not figure out what are really units. I usually just walked past units. Also, I am curious if morning and afternoon is a unit as well.

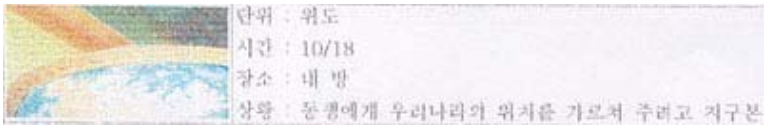
It seemed that the students do not understand the algebraic features of the units and are having a hard time. For example, if you add 4 ‘mornings’ it does not equal a day, but if you add 1hour 24 times it equals a day. Units must be able to be measured and be converted to other units. Also, the physical quantity of a unit must be measured by a measuring tool, but prefix ‘uk’ for number and ‘wee’ for ranks can not be measured.

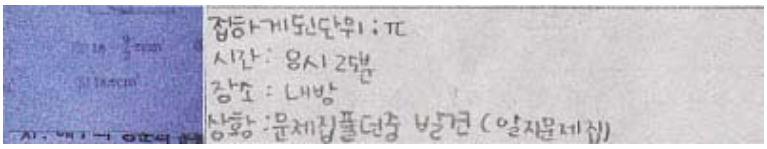
<table>
<tr><td rowspan="6">Non-units</td><td> 

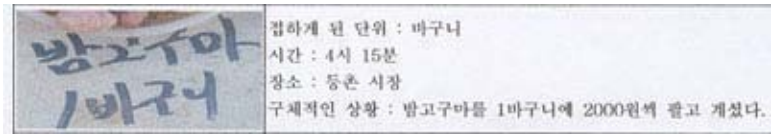
(a) V(a symbol of volume), P(a symbol of pressure)</td></tr>
<tr><td> 

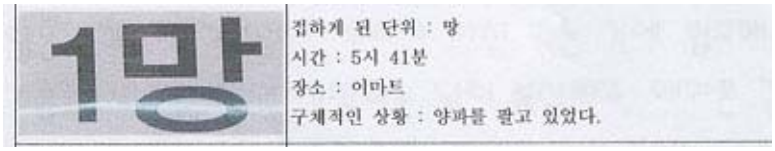
(b) ‘Uk’ (a Korean prefix same to one thousand million)</td></tr>
<tr><td> 

(c) ‘Ohu’ (afternoon)</td></tr>
<tr><td> 

(d) ‘Dae’ (large)</td></tr>
<tr><td> 

(e) latitude</td></tr>
<tr><td> 

(f) phi</td></tr>
<tr><td rowspan="2">Unscientific units</td><td> 

(g) ‘Baguni’ (basket)</td></tr>
<tr><td> 

(h) ‘Mang’ (net)</td></tr>
</table>

Figure 6. Non-units and Unscientific units Considered as Scientific Units by Students

Cases of (g) and (h) in Figure 6 illustrate the unscientific units which were considered as scientific ones by the students. In this study, we claim as unscientific units some counting units (such as 1 Cheung, 1 Ccyol-rea, 1 Mari, 1 Poki) and units without the standard (such as, 1 Bbeum, 1 Zum, 1 Jim). The unscientific units that students are confused about are ‘Baguni(basket)’, ‘Mudoeki’, ‘Bong(plastic bags)’, ‘Mang(which you put onions in)’ which are used by

people for convenience. These kinds of optional units are different form scientific units which the standards are important and can be used only in real life. These kinds of units are particular units used in the neighborhoods groceries stores only. On the contrast, scientific units have the characteristics of standardization and universality.

5. Conclusions

The findings of this study can be summarized as follows.

Firstly, the learning of units that are easily seen in life has a trend of being taught late. Time and length units that are easily seen in life are taught in low elementary grades. Nevertheless, distains units and some measurement units that can be found easily in grocery stores are taught in 4th grade math. Also, units like A, V, Ω, W that can be found in home appliances, are taught in 8th or 9th grade science. The learning of units seems too late compared to the time when students get in touch with the units in everyday life.

Secondly, we get in touch with a lot of units in everyday life. However, the textbook do not present various kinds of scientific units used in everyday life. The units that were found in the 'finding the units in everyday life' activity can be used as the examples for everyday life units in the textbook. Units of everyday life that were presented in the science textbooks were about 10 times, less than of those in the math textbooks. Since units are important in the communication of science and one of the main goals of the science subject in the 7th National Curriculum is 'real life', the science textbooks need to present more everyday life units.

Thirdly, in 'preceding research[6]' that was done 20 years ago, there were a lot of inscription violations. However, textbooks that are published now-days seemed to be following the regulations pretty well. Nevertheless, there might be frustration by students because in real life the inscriptions of units are not written correctly and many other non SI units are used.

Fourthly, some Non-SI units which were used often in everyday life are introduced in the textbooks. This means that it has been improved very much than the time the 'preceding research' was done. Nevertheless, still Non-SI units like 'Guen', 'Peoung', and 'inch' are used in everyday life, but we could find that the traditional Cuk-guwan-bubb's usage has decrease a lot.

Fifthly, after analyzing the students' reports, we found that students were confused units with symbols. Some students were confusing prefixes with units. Moreover, some students thought that scientific terms and standards were units as well. It seems that this is because students do not know algebraic characteristics and the possibility of measurement and the standardization of scientific units as well as its universality. Also, scientific units and unscientific units are mixed in everyday life and that is causing the confusion to get worse. Schools need to teach about units more clearly and the society needs to be guided to use units correctly.

We have shown that the contents of textbooks related to units dose not bind with everyday life. The way that students get in touch with units is both through the textbook and everyday life. So, if the two does not correspond, it will be difficult for students to learn units. Although there has been a considerable improvement of using SI units correctly, the correct usage itself does not help the students learn about units. In order for students to learn units and use them for proper communication, we must decrease the gap between the textbook and everyday life. In conclusion, in order to learn correctly about units, we must combine everyday life and the correct units, and the correct usage of units in real life is required.

In addition, there is a need for further research about massiveness (i.e. feeling of the scale). Unit learning can be divided into two parts, 'understanding physical concepts' and 'learning about massiveness'. For example, '10 N' includes the concept of force (embedded in the unit of N) and the numerical value of the massiveness for that particular '10 N'. Students need to know not only the conceptual relationship between force and N but also the fact that 10 N is equivalent to the weight of 1 kg of mass. The massiveness needs to be taught along with physical concepts. This issue needs to be studied further as an important part of the research toward the teaching and learning of scientific units.

6. References

[1] K. H. Choi and S. J. Kim, "The Development of Evaluating Framework for a Science Textbook in a Secondary School," *Journal of Korea Association for Research in Science Education*, Vol. 16, No. 3, pp. 303-313, 1996.

[2] S. Y. Lee, "Middle school student's perception about science units & factors affecting their understanding of units appeared from problem solving activities," Master Thesis, Seoul National University, 2004.

[3] BIPM, *The International System of Units(SI)*, 7th ed., Sevres, 1998.

[4] www.klaw.go.kr

[5] ISO, *ISO Standards Handbook: Quantities and units*, 3rd ed., International Organization for Standardization, Geneva, p. 345, 1993.

[6] Y. H. Shin, J. S. Kang and C. H. Kim, "A Study on Dissemination of SI in the Primary and Secondary Educational Systems,", Korean Physical Society, "Physics Education", Vol. 2, No. 1, pp. 3-13, 1983.

[7] J. A. Soh, H. K. Jong, Y. J. Jung, "Investigation on the Students' Abilities of Reading Scales and Conceptions Related with Measuring Instruments and Units," *Journal of Korea Association for Research in Science Education*, Vol. 20, No. 1, pp. 1-11, 2000.