# Web Page Design Standards for Physics Teachers

**Sungmuk Lee, Jeongwoo Son, Youngseok Jhun**

## Ⅰ. Introduction

With the rapid development of computer network technologies, there have been a number of recent studies on the use of the Internet in education, particularly on the use of the World Wide Web (the Web) for Web-Based Instruction (WBI). WBI can be defined as the instructional activities which provide purposeful interaction to increase learners' knowledge or skills through specific and pre-planned methods[1]. It allows self-directed, self-paced, and multimedia-assisted learning. Thus it is an instruction and learning system which is based on the exchange, acquisition, and creation of information on the Internet[2].

Currently, many Web projects are being implemented which can be classified into three categories: communication, problem solving, and information collection. Along with these categories, WBI is specially efficient for the construction of learning environments based on constructivism[3]. It offers easy selection of instructional goals, diversity of materials presentation, actual learning environments, various kinds of interactions, and scope for the reflective thinking process.

Educational materials for WBI need to be developed by the teacher him/herself or need to allow the teacher to modify them in some way. Considering different levels of students' abilities and unexpected events which may occur during lessons, the positive effects of instruction can be achieved only when the teacher has the means or skills to modify or change Web pages for instruction. As Web pages can be created in relatively quick time with minimum effort and can be shared and modified easily, it seems desirable to construct Web-based instruction and learning systems. Web-based educational programs can increase their quality levels by responding to feedback from many users and by using other developers' programs with easy linking and modifications.

In order to make progress in the construction of Web-based instruction and learning systems, Web page design standards should first be identified as a step toward the standardization of Web-based materials presentation. When the construction of Web-based instruction and learning systems follows the standards, the degree of application can be maximized.

The aim of this study is to suggest Web page design standards for physics teachers who plan to develop WBI materials. For accomplishing this aim, the authors have addressed two key factors: content and the characteristics of Web pages for physics.

For content standards of Web pages for physics, the authors rebuilt a framework of the Third International Mathematics and Science Study (TIMSS)[4] in a way to develop, modify, and complement consistent learning materials. On the other hand, standards for the characteristics of Web pages for physics are drawn up with a consideration for the construction process of electronic textbooks in the Internet School Project at Seoul National University. These standards are applied to the analysis of existing electronic textbooks and are tested for their reliability. This study finally investigates how Web pages developed by these standards provide learning environments.

## II. Content standards of Web pages for Physics

The structure of knowledge on the Web takes a non-linear approach which allows learners to access non-sequential information and to explore the information according to the learners' preferences or needs. As learners gain new knowledge by discovering needed information and interacting with other people on the Web, they are able to increase their abilities in creativity, diversity, and autonomy through use of the Web. This kind of Web development has made the form of learning expand freely and has provided educational environments where learners can study for themselves without any help from instructors[5].

It is suggested that Web pages for physics should be based on the National Curriculum and cover various categories in physics so that, with small modifications, they can be used even after the revision of the National Curriculum. The content standards presented in this paper were developed by modifying the content aspects of TIMMS which was used for the comparison of international achievement in mathematics and science. Using the standards, the authors analyze the contents of the Web pages "Physics Class in Internet School by the College of Education, Seoul National University" which is the only Web site containing all chapters of the physics textbook.

Table 1 shows the content standards and the results of a comparison between the contents of "Physics Class in Internet School" and those of the National Curriculums (6th & 7th). The standards employed the framework of TIMMS in dividing into high and low categories, and the lesson contents were newly categorized to include each physics concept suggested by TIMMS. In classifying the existing Web pages, the authors looked at whether the low categories contain the same concepts as those of the lesson contents. In the 6th Curriculum, the lesson contents were based on Physics I, II textbook. Newly added contents in the 7th Curriculum were also included in the lesson contents.

Of the 70 contents identified in the whole lesson contents, the Web pages of "Physics Class in Internet School" covers 41 contents, the 6th Curriculum covers 44, and the 7th Curriculum covers 46. The number of contents developed by the Internet School but not included in the National Curriculum is 6, while the number of contents included in the National Curriculum but not developed by the Internet School is 11. From this analysis, we can get an idea of the specific areas which need more learning materials than others and what contents are required to be further developed for physics instruction.

<Table 1> The analysis of the contents of the Internet School according to contents standards

| high category | low category | contents in detail | subject of unit in Internet School | 6th National Curriculum | 7th National Curriculum |
|---|---|---|---|---|---|
| 1. Physical changes | 11.properties ofmatter | 111 changes in states of matter | Heat phenomenon by molecular motion | | |
| | | 112 mass, volume, and density | | | |
| | | 113 expansion of object by heat | Heat phenomenon by molecular motion | ○ | ○ |
| | | 114heatcurrent | | | |
| | 12. kinetic theory of molecular | 121.gaslaws | Heat phenomenon and molecular motion<br>Molecular motion of gas<br>Heat phenomenon by molecular motion | ○ | ○ |
| | | 122. thermodynamical laws | Thermodynamic process and law of thermodynamics | ○ | ○ |
| | 13.quantum theory and fundamental particles | 131. duality of light and photoelectric effect | Photoelectric effect<br>Duality of light | ○ | ○ |
| | | 132.dualityofmatter | Material wave<br>Compton effect | ○ | ○ |
| | | 133. atomic structure | Atomic model | ○ | ○ |
| | | 134. structure of nucleus | Structure of nucleus | ○ | ○ |
| | | 135. nuclear reaction and radioactivity | Nuclear reaction and radioactivity<br>Nuclear energy | ○ | ○ |
| | | 136. fundamental particles | Discovering electrons | ○ | ○ |

| | | | | | |
|---|---|---|---|---|---|
| 2. Energy and physical processes | 21.energy types, sources, conversions | 211. various types of energy | Feel energy! | ○ | ○ |
| | | 212. changing the form of energy | Work from energy<br>Conservation and conversion of mechanical energy | ○ | ○ |
| | | 213. work and energy | Work<br>Present Energy! | ○ | ○ |
| | | 214. efficeincy of energy transfer | Thermodynamic process and law of thermodynamics | ○ | ○ |
| | 22.heatand temperature | 221. temperature scales | Heat phenomenon and molecular motion | ○ | ○ |
| | | 222. heat as a form of energy | Molecular motion of gas | ○ | ○ |
| | | 223. heat versus temperature | Heat phenomenon and molecular motion | ○ | ○ |
| | | 224.moving of heat | | ○ | ○ |
| | 23. wave pheonmena | 231. wave properties | Generation and shorts of wave<br>Description of wave<br>Reflection of wave<br>Refraction of wave | ○ | ○ |
| | | 232. wave types | Generation and shorts of wave | ○ | ○ |
| | | 233. wave interactions | Superposition of wave<br>Diffraction of wave<br>Interference of wave | ○ | ○ |
| | 24.sound and vibration | 241. simple harmonic oscillation | | ○ | ○ |
| | | 242. transmission of sound | | ○ | ○ |
| | | 243. acoustics | Use of sound wave | | |
| | | 244.harmonics | Use of sound wave | | |
| | 25. light | 251.nature of light | Properties of light | ○ | ○ |
| | | 252.light propagation | | | |
| | | 253.luminosity | | | |
| | | 254.lens andmirror | Image by lens and mirror | | |
| | | 255. diffraction and interference | Diffraction and interference of light | ○ | ○ |
| | 26. electricity | 261. static electricity | Electric field and **electric potential** | ○ | ○ |
| | | 262. elecric fields and potential | Electric field and **electric potential** | ○ | ○ |
| | | 263. alternating current | | | ○ |
| | | 264.direct current | Current | ○ | ○ |
| | | 265. capacitor | Electric field and **electric potential** | ○ | ○ |
| | | 266.joule heat | Heat phenomenon and molecular motion | ○ | ○ |
| | 27. magnetism | 271. magnetic properties | | ○ | ○ |
| | | 272. electric current and magnetic field | | ○ | ○ |
| | | 273. electromagnetic force | | ○ | ○ |
| | | 274.induced current | | ○ | ○ |
| | | 275. electromagnetic wave | | | ○ |

| | | | | | |
|---|---|---|---|---|---|
| 3. Force and motion | 31. types of forces | 311. action of force | | | |
| | | 312.gravitational force | Forces | ○ | ○ |
| | | 313. friction | Forces | ○ | ○ |
| | | 314.electric force | Electric field and electric potential | ○ | ○ |
| | | 315.magnetic force | | ○ | ○ |
| | | 316.buoyancy | | | |
| | | 317.elastic force | Forces | | |
| | 32. time, space, and motion | 321.measurement of time | | | |
| | | 322. velocity and acceleration | Velocity<br>Composition of velocity<br>Acceleration<br>Relation of motion variables<br>Velocity and acceleration | ○ | ○ |
| | | 323.linear motion | Motion in gravitation field | ○ | ○ |
| | | 324. rotational motion | Circular motion and simple harmonic motion | ○ | ○ |
| | | 325. reference frames for motion | | ○ | ○ |
| | | 326. 2-dimensional motion | Universal gravitation and motion of planet | ○ | ○ |
| | 33. dynamics of motion | 331. equilibrium and addition of forces | | | |
| | | 332. Newton's law of motion | Newton's first law<br>Newton's second law<br>Newton's third law<br>Newton's law of motion | ○ | ○ |
| | | 333. momentum and impulse | Momentum and impulse<br>Conservation of momentum<br>Law of momentum conservation | ○ | ○ |
| | | 334.inertial force | | | |
| | 34. relativity theory | 341. mass/energy/velocity relationship | | | |
| | | 342. principle of constancy of light velocity | | | |
| | | 343. time delay and length contraction | | | |
| | 35. fluid behavior | 351.pressure | | | |
| | | 352.hydraulics | | | |
| | | 353.bernoulli theorem | | | |
| | | 354.pneumatics | | | |
| | | 355. capillarity and surface tension | | | |

Web pages developed under the ultra-curricular standards can help conserve effort and resources because there will be no necessity to change the basic structure even when the National Curriculum is revised. For example, an electronic textbook, which is being developed by Edunet[6)], has been compiled with the 6th Curriculum, so it will have to be changed entirely after the 7th Curriculum is introduced.

Bearing in mind that a strong point of Web pages is that they provide self-directed and self-paced learning environments, the contents can be re-composed in accordance with the variation of the curriculum, and can be adapted to supplementary materials which satisfy learners' needs, providing that the contents are developed with the aid of systematic content standards.

## Ⅲ. Standards of the characteristics of Web pages for Physics

General considerations for designing WBI can be applied to the evaluation of WBI, considering an idea that design factors and evaluation factors are complementary to each other. Several theories and methods[1)7)8)9)10)11)] related to those factors can be easily found on the Internet. In this section, the authors analyze the contents of "Physics Class in Internet School" from the following four perspectives so as to establish standards of the characteristics of Web pages in the area of physics.

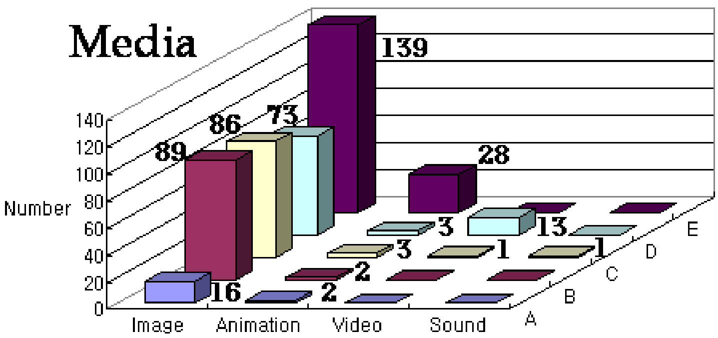
First, the authors identified and countered the types and numberofmultimedia used in each sub-unit of Web pages. Although using many different types of multimedia does not guarantee that it will take full advantage of the capabilities of the Web, it gives various kinds of information in comparison with text, so learners' interests and the amount of information collected vary depending on the types and number of multimedia. Each learner would have a different opinion on the most effective type of multimedia for his/her learning. Multimedia is classified into four types here: images, moving pictures, animation, and sound.

Second, the authors countered the number of hyperlinks after dividing them into simple-links and continuous-links. When learners activate hyperlinks by clicking them on, a simple-link serves as a provider of a single stream of information and has no outgoing links or other window, while a continuous-link is connected with others and has many links. As in the use of multimedia, using a large number of hyperlinks does not guarantee that it will take full advantage of the capabilities of the Web. Necessarily, the misuse of hyperlinks would cause worse results than not using them at all. However, hyperlinks clearly characterize the Web, with the linking of relevant learning materials, which does not exist in traditional textbooks. In this study, hyperlinks simply going to the next page and magnifying images or viewing other windows are excluded, and a main focus is given to the body of the Web pages for the analysis of the use of hyperlinks.

Third, the authors countered the number of physics concepts delivery through simulation programs. Most concepts in physics can be effectively presented by using simulation programs. This allows an increase learning efficiency, particularly by changing various variables of simulation in the programs. Importantly, learning outcomes would be different depending on the methods of simulation of physics concepts. This section attempts to answer the question of how many times the Web pages used simulation to help learners understand concepts.

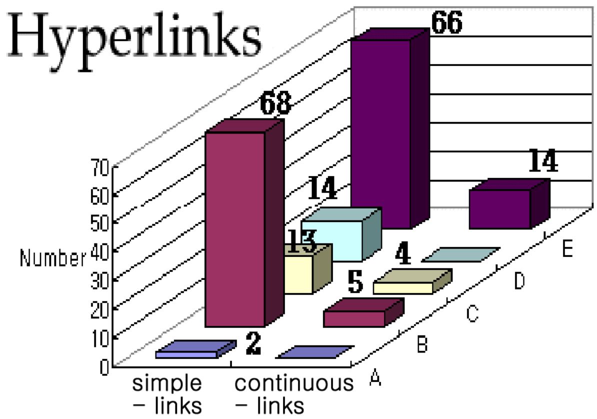
Finally, the authors investigated the availability of feedback factors. The type of feedback analyzed in this study include informing learners of how much they studied and achieved in the learning of physics. Thus, feedback here means providing an immediate decision about correct answers and explanations about test items in the body of the Web pages. Simple answers offered in the tests are excluded in the discussion of feedback; they are examined in the discussion of hyperlinks.

All developed Web pages were initially analyzed, but only the total number of each unit is presented here. Figures 1-1, 1-2, 1-3, and 1-4 show the results of the analysis.



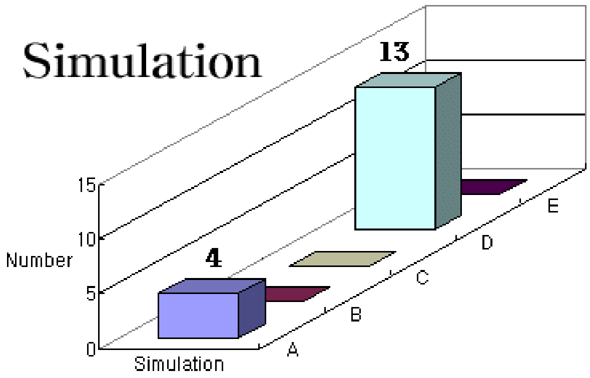

A: Force and Motion
B: Energy
C:Electricity and Magnetism
D: Wave
E: Modern Physics

<Figure 1-1> The number of media forms



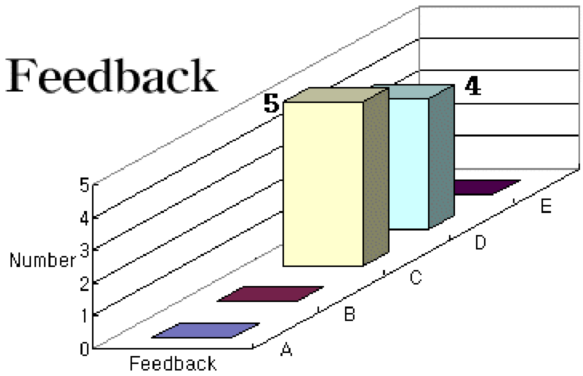

A: Force and Motion
B: Energy
C:Electricity and Magnetism
D: Wave
E: Modern Physics

<Figure 1-2> The number of hyperlinks




A: Force and Motion
B: Energy
C:Electricity and Magnetism
D: Wave
E: Modern Physics

<Figure 1-3> The number of simulation




A: Force and Motion
B: Energy
C:Electricity and Magnetism
D: Wave
E: Modern Physics

<Figure 1-4> The number of feedback

The rate of use of each medium shows that images were used 88.38%, animation 8.33%, moving pictures 3.07%, and sound 0.22%. In relation to hyperlinks, simple-links were used 87.63% and continuous-links 12.37%. Simulation and feedback were developed for some specific units only. This indicates that only units containing appropriate content for Web presentation were developed.

In brief, the Web pages developed for "Physics Class in Internet School" does not fully utilize the characteristics of the Web. This is due to (1) excessive use of images in the use of media; (2) no provision for free learning styles because simple-links were used solely in most hyperlinks; (3) lack of simulation for presenting physics concepts; and (4) unavailability of feedback for problem-solving.

In order to make good use of the characteristics of the Web, multimedia materials must be developed which match lesson contents appropriately. As shown in Figures 1-1, 1-2, 1-3, and 1-4, some units contain relatively many animation and simulation presentations in comparison with other units. This implies that developers who developed the Web pages tended to heavily rely on text and images without any consideration of advantages of the Web. Therefore, there is a great need for design standards utilizing the characteristics of the Web.

Unlike previous research on design standards which focused on the layout[12)] and amount of multimedia,[13] this study suggests standards in terms of four types of multimedia discussed earlier. The following standards are based on the problems identified in the analysis of the present state of the "Physics Class in Internet School" Web pages, the authors' experiences in teaching and developing teaching materials,[14)] and the analysis of the findings reported in a paper entitled "A report on the situation of using Cyber High School" (1999).[15)]

First, as multimedia is the most appropriate tool for presenting contents, developers need to develop multimedia materials in advance before making Web pages. In doing so, contents should first be analyzed, and then suitable media types should be decided on the basis of the analysis.

① Diversity of materials: If Web pages contain text materials only, then learners would choose textbooks instead of Web pages. For this reason, multimedia materials in Web pages should be presented with brief explanations and essential contents. At the same time, explanations of physics concepts need to be presented with the aid of animation, moving pictures, or simulation effects.

② Explanation of multimedia materials: Learners will not be able to grasp the meanings of simulation or moving pictures if they are presented unclearly and ambiguously.

③ Natural phenomena should be presented in the form of moving pictures rather than images.

④ The expansion of numerical formulas should be presented in the form of animation.

⑤ The application or reading of daily lives should be presented in the form of images.

⑥ Experiment-based contents should be presented appropriately in the form of animation.

Second, after identifying the relationship between contents of each unit, hyperlinks should be employed to allow learners to decide their own learning paths.

① Simple-hyperlinks should be used to explain simple terms.

② Structure of screen displays which allows learners to check their own learning paths: When concepts are explained, the concepts should be linked with related Web pages for continuous learning. In this respect, Web designers need to pay attention to the overall structure of screen displays and design the structure carefully so that learners can explore the Web pages without getting lost in working through their learning paths.

③ Provision of search functions: Results of searching for terms should be presented in separate windows in order to provide materials related to essential terms. In this regard, materials for explaining terms and CGI programs for searching terms should be prepared.

Third, numerical formulas used in physics can be simulated. Therefore, if developers have programming abilities, they would be able to use many kinds of methods for simulation. However, there is no need to simulate all formulas. Simulation should be used only when the improvement of learners' abilities for variable control is requested or when the presentation of concepts involves difficult experiments to conduct in actual situations.

① Presenting physics concepts acquired by experiments with the aid of simulation programs: Simulation materials should be used which allows learners to control variables freely. If Java Applets are used, learners will be able to change variables easily so that the learner-content interaction[16] will occur in the process of learning.

② Developing simulation programs in common ways: Programmers should not develop simulation programs according to their subjective tastes. Depending on how to approach to the learning of concepts, the influence on learners' learning will be different even in the presentation of the same concepts. If needed, make links with materials in other Web sites and use them through hyperlinks. It must be useful for the variety of WBI if learners could use learning materials presented in cyber experiment Web sites[17][18] which are already famous to a lot of people on the Internet.

③ Using CGI programs to allow learners to understand experiment results: To help learners understand experiment results, there is a need for CGI programs which can detect correct or wrong answers by checking essential words in learners' input sentences. By using the programs, it would be also possible to provide immediate feedback.

Fourth, developers should give explanations for all possible cases beforehand to give learners immediate feedback on all test items. They should also consider the effective method of feedback presentation.

① Providing feedback on the reasons for wrong answers : It is good for learners to check their learning achievements with tests immediately after learning concepts. In checking the learners' answers, feedback should provide the reasons for wrong answers, not simply provide the right answers.

② Using check links for previously learned contents: If necessary, pages should be linked with previously learned contents pages for review of physics concepts required for solving problems.

## Ⅳ. Construction of learning environments through Web pages

The main characteristics of WBI are based on the roles of the Web in information sources using hypermedia and multimedia, and in the interaction generated on the Internet through electronic mail and other communication tools.

The acquisition of knowledge in actual experiences occurs in relative and various forms. Accordingly, learning environments supported by active learning should allow learners to learn by themselves through experiences and to find out meanings from their experiences. Web pages seem to respond to this need by making use of hypermedia materials which let learners have these experiences in various ways.

Learners learn when they solve problems in learning environments which are similar to real-life situations. Here, similar environments do not mean the physically same environments as the real world but environments which demand learners' cognitive abilities with similar complexity to the real world. Web pages can offer those environments through simulation programs.

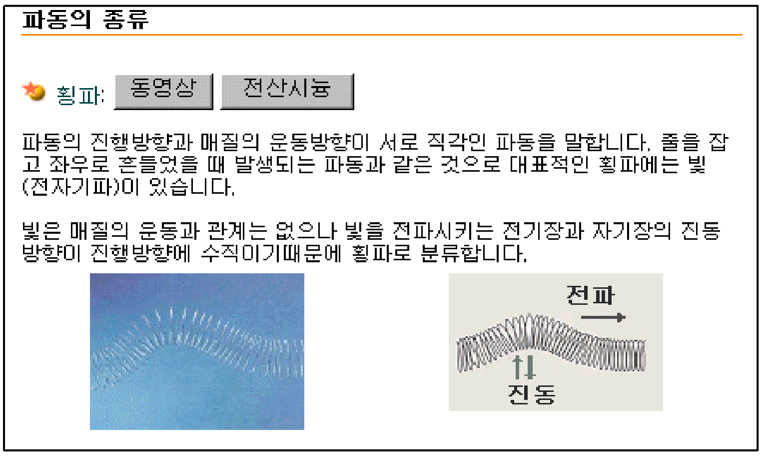
It is argued that learners are able to build their own perspectives and skills for problem-solving while experiencing various views and aspects in cooperative and interactive environments rather than in isolated environments. Thus learners are requested to study actively and positively through cooperative learning, which is based on the communication between learners, not through individual intellectual activities. This means that effective learning depends on the degree of meaningful interaction between the teacher and learners. WBI produces interaction through bulletin boards and discussion rooms, while Web pages guide learners to interact with contents and to communicate with the contents through feedback.

In the teaching of physics, learning environments are based on and formed from contents for WBI that can be created by learner-centered active learning environments, authentic learning, and interactive and cooperative learning, with presentation support of various types of hyperlinked materials, learner-content interaction, and reflective thought through feedback.

In order to see how Web pages provide learning environments, the authors examined learning environments created in "Optics On-line Study at High School" (http://optics.snu.ac.kr/on-line/hischool/) which adapted contents standards of Web pages for physics.

① Presentation of various materials by using hyperlinks

As shown in the "Generation and Types of Wave' page (http://optics.snu.ac.kr/on-line/hischool/wave/section1/html/wave11.html) (Figure 2), a Web page can increase learners' interests by providing not only texts but also various media such as moving pictures, simulation, and images within the page.

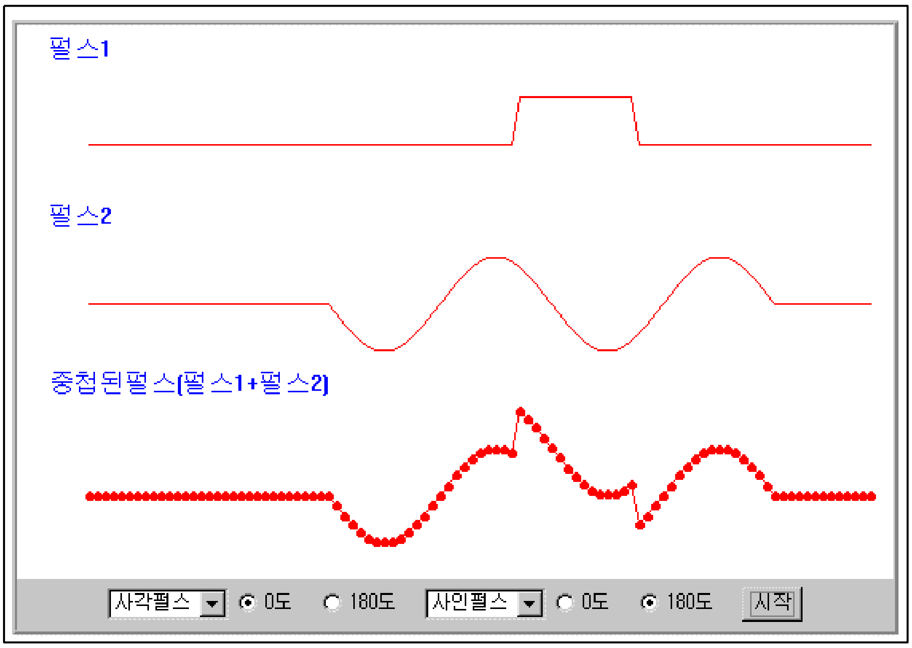



<Figure 2> Use of multimedia

② Learner-content interaction through simulation

As shown in Java Applets of the "Superposition of wave" page (http://optics.snu.ac.kr/on-line/hischool/wave/section1/html/superOfpls.html) (Figures 3-1 and 3-2), learners have options to choose the type of wave and phase. This is one of the methods that generate the leaner-content interaction through simulation. Learners interact with the results of experiments because learners get instant results by instant changes of variables.

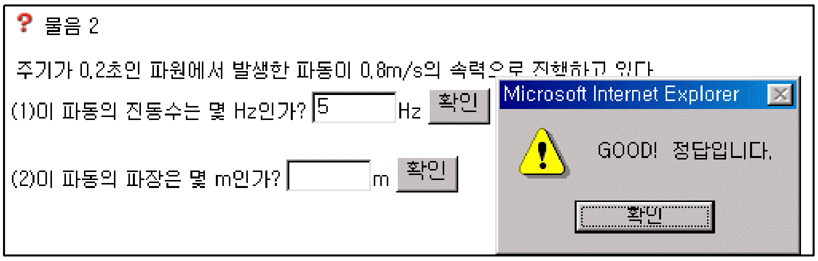

<Figure 3-1> Control of variables



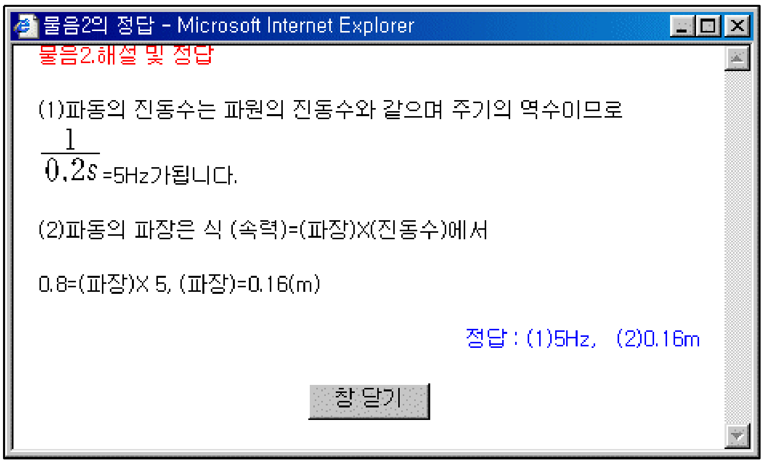

<Figure 3-2> Use of simulation

③ Reflective thought through feedback

In the "Description of wave" page (http://optics.snu.ac.kr/on-line/hischool/wave/section1/html/wave12.html) (Figures 4-1 and 4-2), feedback for correct answers or wrong answers is provided according to learners' input. Through this feedback, learners can have chances to check their answers. They can also have time to rethink the reasons for their choices by clicking on explanation buttons.




<Figure 4-1> Feedback using a form-field




<Figure 4-2> Confirmation of thinking

## V. Conclusion

This study has analyzed a current WBI learning system, "Physics Class in Internet School" by the College of Education, Seoul National University, from the viewpoints of contents and the characteristics of the Web, and suggested Web page design standards for physics teachers who intend to create WBI contents.

Through the analysis, firstly, it has been pointed out that WBI contents should be developed according to a new classification system, which is accepted widely and, at the same time, will not be influenced by any change of curricula. It is recommended that a curriculum for physics needs to be developed as an independent curriculum, which contains contents classified on the basis of basic physics concepts; because, if contents are developed according to the National Curriculum, there will be waste of sources in changing the contents whenever the Curriculum changes or revises its contents. The design standards were suggested through the review of TIMMS's curriculum and were shown in Table 1 in Section II.

Secondly, in order to develop well characterized Web pages content standards, the contents of the "Physics Class in Internet School" Web site have been analyzed in terms of the use of four components such as multimedia, hyperlinks, simulation, and feedback. Based on the analysis of the four components ofthe Web pages, WBI contents standards for physics have been identified and established in this study. The application of the standards could be found in the example Web pages presented in previous sections.

Finally, this study has shown that the suggested contents standards of Web pages provide the diversity of materials presentation by using hyperlinks, learner-content interaction through simulation, and reflective thought through feedback.

Considering that the learning or studying of physics involves understanding theories and conducting experiments, experiments conducted on the Web can be considered as cyber experiments which have unique and powerful features in the control of variables and the instant analysis of experiment results. In addition, theories presented on the Web can be helpful to learners in understanding concepts effectively with the aid of various types of multimedia. Based on these characteristics of the Web, it is clear that further efforts to find appropriate methods for presenting and teaching concepts should be undertaken, for effective Web-based instruction.

## References

1 Ritchie, D. C. & Hoffman, B. Using Instructional Design Principles to Amplify Learning on the World Wide Web
http://edweb.sdsu.edu/clrit/learningtree/DCD/WWWInstrdesign/WWWInstrDesign.html, 1996. 4

2 Hyun-ju Kim, Ok-Hwa Lee & Hong-Gi Kim, Analysis of Web-Based-Instructional Projects and the Proposal of Korean WBI model, Korea Association of Computer Education Journal Vol. 1-1, 1998. 6

3) Hong-Rae Kim & Ki-Sang Song, The Design and Implementation of Web-Based Virtual School in Constructive Approach, Korea Association of Computer Education Journal Vol. 1-1, 1998. 6

4) TIMSS International Study Center, Boston College, http://wwwcsteep.bc.edu/timss

5) Korea Education & Research Information Service, Character and Assessment-criterion of Web Based Instruction,
http://www.kmec.net/malsm/wbi/1/wbi1.html

6) Edunet Middle School, http://edunet.kmec.net/menuservice/1.mnu/2.mnu/index.html

7) Aprendio Inc., Planning Web-Based Training: Four Checklists,
http://www.aprendio.com/checklists.html

8) D. James, Design Methodology for a Web-Based Learning Environment,
http://www.lmu.ac.uk/lss/staffsup/desmeth.htm

9) Harold Henke, Evaluating Web-Based Instructional Design,
http://scis.nova.edu/~henkeh/story1.htm

10) Philip Duchastel & Sue Spahn, Design for Web-Based Learning,
http://www.nova.edu/~duchaste/design.html

11) Thomas McManus, Special Considerations for Designing Internet Based Instruction,
http://ccwf.cc.utexas.edu/~mcmanus/special.html

12) John Morkes & Jakob Nielsen, Concise, SCANNABLE, and Objective: How to Write

for the Web, http://www.useit.com/papers/webwriting/writing.html, 1997

13) Park, I., "Ch5. Contents design of Web-based Education", Web-based Education, 교육과학사, 1999

14) Optics Laboratory, Department of Physics Education, College of Education, Seoul National university, On-line Study, http://optics.snu.ac.kr/on-line/index.html 1998. 4

15) Internet School, A Report on the Situation of Using Cyber High School, College of Education, unpublished, 1999. 10

16) Moore, M. G. & Kearsley, G., Distance Education. Belmont: Wadsworth Publishing Company, 1996

17) Fu-Kwun Hqang's Virtual Physics Laboratory, http://www.phy.ntnu.edu.tw/~hwang/index.html

18) Dong-Jun Lee, Virtual Science Lab, http://www.science.or.kr/lee/