

The Influence of Web-based Intelligent Tutoring Systems on Academic Achievement and Permanence of Acquired Knowledge in Physics Education*

Mustafa Erdemir

Kastamonu University, Kastamonu, Turkey

Şebnem Kandil Ingeç

Gazi University, Ankara, Turkey

This study aims to determine the influence of distance asynchronous teaching of Physics-I topics via intelligent tutoring systems (ITSs) on academic achievement and permanence. A Web-based learning environment was created by use of an ITS called “Turkish Intelligent Tutoring System” (TURKZOS) for such Physics-I units as work, energy, and conservation of energy. The experimental group of the study consisted of 26 students who had computer and Internet access and participated in the study voluntarily. The achievement test developed by the researchers was used for collecting data. This test was conducted as pre-test and post-test before and after the experimental procedure respectively. The same test was administered to measure permanence 45 days later following the performance of the post-test. The obtained data were analyzed via paired *t*-test. Mean pre-test score was found to be $\bar{x} = 23.88$, and mean post-test score was found to be $\bar{x} = 73.80$. Mean permanence test, on the other hand, was found to be $\bar{x} = 71.88$. When mean pre-test and post-test scores were compared, a significant difference was identified in favor of the mean post-test score ($p < 0.05$). In addition, a significant difference was detected between mean permanence test and pre-test scores ($p < 0.005$). The mean permanence test score was higher than the mean pre-test score. It was concluded that intelligent learning environments created through Web-based tutoring systems have a positive influence on academic achievement and permanence in physics teaching.

Keywords: physics education, distance education, Web-based intelligent tutoring system (ITS), academic achievement and permanence

Introduction

Lifelong learning has become one of the primary goals of education. Education has always been a main issue since the start of humanity. Studies and research on learning and teaching existed in the past, exist now, and will continue to exist in the future. Educational experts carry out studies and research in order to adapt developments in science and technology to learning and teaching situations. Attempts are made to introduce technological developments to teaching.

Education continues until death to improve both individual and social life quality. Continuous learning

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Mustafa Erdemir, M.A., lecturer, Faculty of Education, Kastamonu University.

Şebnem Kandil Ingeç, Ph.D., associate professor, Faculty of Education, Gazi University.

brings about a democratic improvement in economic growth, social welfare, and life (Derrick, 2003). Since learning cannot be achieved in the classroom environment at every age, it sometimes takes place from distance, through technology use and via interactions with the environment. Furthermore, institutions and organizations turn to distance education in order to inform and train their target groups. Distance education refers to a synchronous or asynchronous learning process involving the use of such teaching tools as technological instruments, written materials, and printed materials when students and information source are at a physical distance.

Distance education utilizes various techniques, such as virtual classroom, e-learning, m-learning, Web-based distance education, online learning, and blended education. The improvement of these techniques and the increase of their productivity in educational processes depend on technological developments. For example, advancements in artificial neural networks have enabled more efficient use of computers in educational activities and have contributed to the creation of intelligent tutoring systems (ITSs). Among primary educational technologies are communication technologies, computer technologies, and artificial neural network programmes. Today, studies on education mainly focus on these subjects. In this context, two important fields of study are improving the productivity of computer-supported education and integrating computer programmes, like ITSs into educational processes.

Developments in artificial neural networks have led to the birth of intelligent learning environments, and the combination of these environments with computer-supported education has brought about ITSs. Being new learning environments, ITSs allow the individualization of learning processes, the elimination of time and space obligations, and the systematic access of many people to educational activities. This makes the use of ITSs in education widespread. Moreover, ITSs are the programmes involving processes that are most similar to the behaviors displayed by teachers in teaching processes. ITSs, which refer to an advanced educational approach, offer lesson content to every student through adaptation and imitating teachers. ITSs perceive every student's knowledge level and decide on the next teaching situation to make them reach the maximum level as normal (regular) education does (Jerinic, 2013).

According to Doğan (2006), ITSs are regarded as future's teaching systems, and thus, many studies are carried out in this field. Intelligent teaching systems are the teaching systems that are most similar to the traditional classroom environment. ITSs are quite successful in comparison to other systems (Doğan & Kubat, 2008).

ITSs can adapt to the individual needs of students and the acts of teachers. They aim to achieve teachers' acts. ITSs can provide students with flexible teaching materials, a one-to-one teaching environment, and feedback (Moundridou & Virvou, 2000).

There are some question marks regarding how sensibly information provided in the virtual environment is received and treated by individuals. According to Gustafsson (2002), students cannot complete their learning processes through distance education, which uses technological teaching techniques, and it is difficult to inspect students in this approach. In formal education, social communication among students encourages the continuance of educational activities.

Socialization, group work, and face-to-face interaction in formal education improve achievement and continuity. However, the importance of learning processes based on distance ITSs is undeniable, too.

Technological education must create awareness within the context of social content and influence. Educators need to be prepared for this change. Thus, information environments should be created rapidly.

ITSs aim to imitate normal (regular) teachers by adapting to individuals' (students') strengths, weaknesses, and other characteristics. As students use ITSs, their deficiencies are noticed. Such deficiencies may be overcome by use of different teaching strategies. This brings a big convenience to teachers and students by providing them with a flexibility to eliminate these deficiencies.

The Web-based ITS used in the present study offers a time and space independent asynchronous learning process, which provides those people who cannot receive formal education with an educational opportunity. In addition, it can be used for supporting in-class training. Students employ processes unique to themselves in learning something new or recalling a piece of knowledge acquired beforehand, but such individuality is not taken into consideration enough in the classroom environment.

Web-based ITSs provide students with an educational opportunity that is both time and space independent and free from any problems caused by the Internet environment (İstanbul, 2003). Today, education and technology are intertwined. Although there are already some common educational approaches (e.g., behaviorism, cognitivism, and constructivism), a new theory has been introduced by Siemens (2006) as a learning theory for the digital age: the Connectivism Theory. This theory emphasizes that knowledge is in the external world; it is consumed very fast; the process of reaching it continues for life time; developing digital technology is required for reaching it; and for all these reasons, there is a need for such a theory.

Achievement and Permanence

Curricula and teaching and assessment processes of educational institutions focus on students' achievement. However, students at the same age may have different learning processes and perceptual states. Some students may learn very rapidly, while some others learn or reach learning tools very slowly. To improve achievement and permanence, non-common states (characteristics) of students must be taken into consideration when preparing and implementing curricula and teaching and assessment processes. It is quite difficult to use learning environments that are made up of non-common states in normal (regular) education. In classroom-oriented education, lesson contents and learning processes are created by assuming that a general perception level prevails among students. In normal (regular) classrooms, learning environments cannot be created based on non-common states (e.g., time, space, individual perception, and the number of students), and learning can be achieved only through adaptable teaching states, which decrease overall achievement. This has a negative influence on permanence because it is related to the continuity of achievement.

Teaching lessons via adaptive Web-based ITSs may provide advantages about time, space, individual perception, the number of students reached, creation of a rich content, and navigational support. These advantages may eliminate problems emerging in the classroom, allow offering individualized lesson contents, and enhance overall achievement.

The use of technology in educational activities is undeniable. One of the primary tools used in education is computer. It is reported that computer-supported education has a considerable influence on student achievement because teachers use computers as an auxiliary tool to concretize abstract concepts (Güven & Sülün, 2012).

Time and space independence is one of the most important benefits of Web-based education, which is considered to have a positive influence on enhanced performance (Demirel, Seferoğlu, & Yağcı, 2001).

ITSs

ITSs are a class of computer-based education systems that allow adaptivity at a certain level. As students

use these systems, teaching strategies are changed and adapted depending on students' progress. Such systems identify the strengths and weaknesses of students, and teachers continue teaching activities in the classroom environment based on such identification, which allows doing necessary updates in these systems (Doğan, 2006).

ITSs allow shaping learning processes according to individuals' needs, affective characteristics, like learning style, and cognitive knowledge levels (Dağ, 2011). ITSs consist of several components for design and conceptualization purposes.

According to Woolf (1992), ITSs are composed of the following four basic components:

- (a) The student module;
- (b) The tutoring module;
- (c) The domain (expert knowledge) module;
- (d) The user interface (communication) module.

The Student Module

It stores the information unique to each student. It monitors how well students do in learning situations. The objective of this module is to collect information for the tutoring module and to make the expert use such information.

While some student modules contain short-term information (i.e., valid for one session), some others make use of long-term information. Short-term information is used for instant assistance. Long-term information, on the other hand, can be used for selecting the best problem or topic appropriate to the student in pedagogical actions (Suraweara, 2004).

Short-term student module. Model monitoring module and constraint-based student module are examples of this module.

Long-term student module. Overlay student module, stereotypes student module, Bayes student module, case-based student module, and agent-based student module are examples of this module. The short-term student module is usually used for updating the long-term student module (Mayo, 2001).

The Overlay Student Module Used in the Study

It involves differences between the expert's knowledge of the topic and the student's knowledge of it. The student's domain knowledge is considered a subset of the expert's knowledge (Stankov, 1996).

The objective of this module is to eliminate deficiencies or wrong knowledge of students and to make them reach the expert's knowledge. It is not approved that students have the knowledge that is not possessed by the expert. The domain knowledge is divided into sections, such as rules, events, and concepts. The degrees to what these sections are known are expressed by ranges. For instance, when the range "0" to "100" is used, "0" demonstrates lack of knowledge, while "100" indicates that the topic is known perfectly. The beginning level of a student is considered "0", and his/her level changes dynamically depending on his/her behaviors (Suraweara, 2004).

ITS General Algorithm Used in the Study

The Web-based ITS used in the study was developed by Karacı (2013). Figure 1 presents the algorithm of the ITS used in the study. After students study all the topics and pages in the related unit at the learning level determined by the teacher and calculated via artificial neural networks, they can enter the exam page. The learning levels of students entering the exam page are calculated based on the assessment method determined

by the teacher. If the calculated learning levels are equal to or higher than the level determined by the teacher, students are directed to the unit or units meeting the requirement for moving up. If the learning level is not enough, the pages in which students have problems are given to students as feedback, and students are requested to study such pages again. If students want to take the exam again without studying these pages, they are not allowed to do so. The above-mentioned procedures are conducted and repeated until students learn all units at the learning level determined by the teacher (Karacı, 2013).

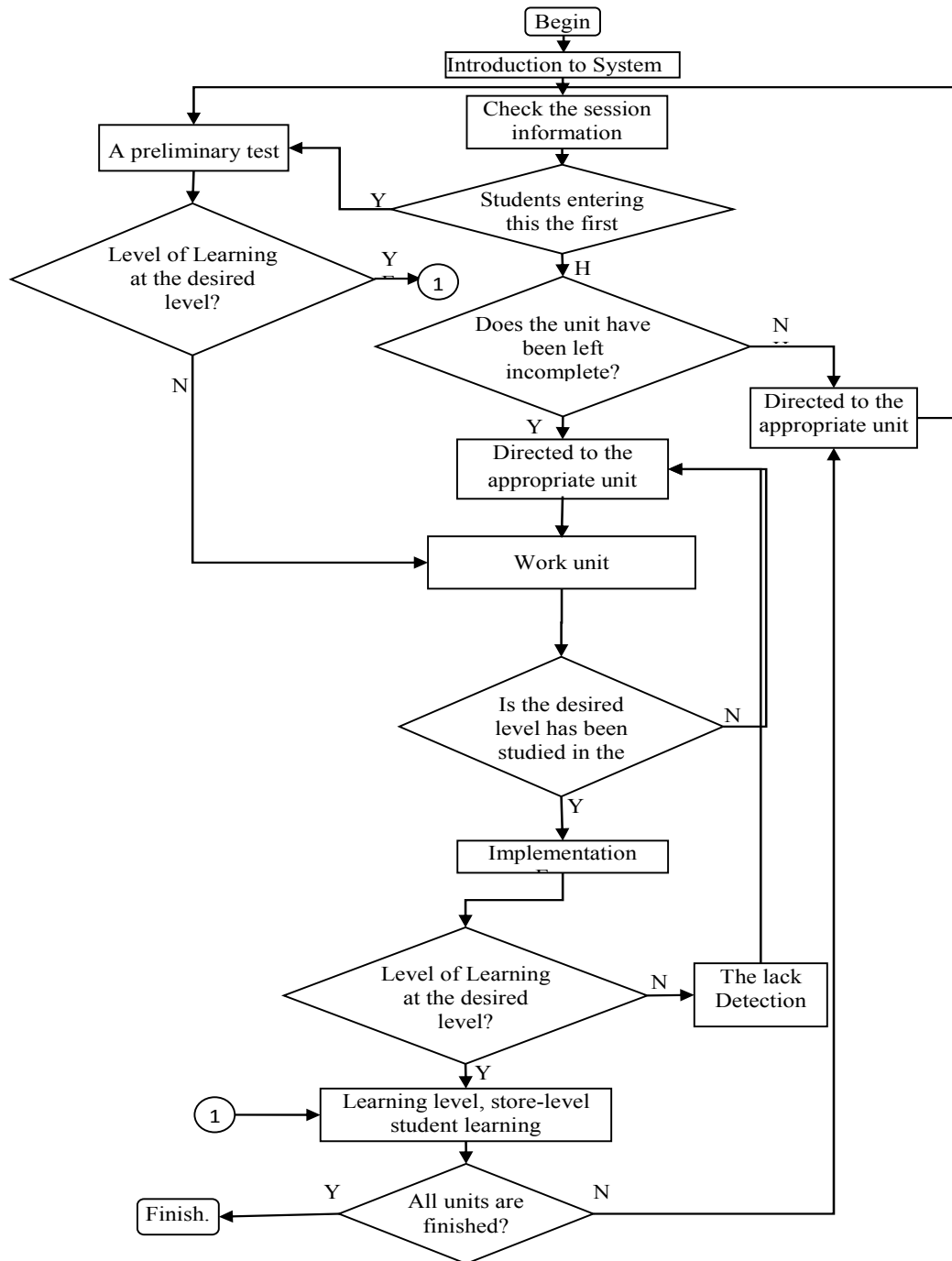


Figure 1. General algorithm of the ITS used.

According to this algorithm, if a student enters for the first time, the first topic titles are opened. If the student entered and studied some topics beforehand, the system directs him/her to the page he/she left off. Those students who enter for the first time study the content including figures, formulas, animations, examples, activities, and lectures prepared by the teacher as well as the links about the related topic and answer the questions on activity pages. Students finishing a topic proceed to another topic. The same study method is employed for each topic in the unit. After students study all of the topics in the unit, they take the end-of-unit exam for moving up. To take this exam, students need to study each content page for a time determined by the teacher. If a student has not studied content pages enough, he/she is directed by the system to relevant pages.

The Intelligence Features Used in the Study

The intelligence features used in the study are explained below.

Remembering the page left off. If a student leaves the page or closes the browser directly, the system directs him/her to the last page visited when he/she enters the system again. When he/she enters the system, he/she continues with the last page displayed.

Stating learning levels. The system reports a student's learning level to him/her (he/she definitely does not know; he/she most probably does not know; he/she possibly does not know; he/she may know; he/she possibly knows; he/she most probably knows; he/she definitely knows; etc.).

Determining the topics in which individuals have deficiencies and directing them to such topics. The system determines the concepts, topics, and pages in which students have deficiencies, directs them to such concepts, topics, and pages, and makes suggestions.

Detecting reviewing situations and directing. When a student does not review the pages which the system recommends him/her to do so, it detects it, prevents the student from proceeding to a new page, and directs him/her to pages in which he/she has learning deficiencies.

Ensuring proper proceeding to new topics. When a student does not satisfy the learning level determined by the teacher as a condition for proceeding, the system prevents him/her from proceeding to the themes established by the teacher.

Opening topics to those who satisfy the conditions for proceeding. When a student satisfies the learning level determined by the teacher as a condition for proceeding, the system brings the themes to which the student can proceed into use and directs him/her by informing him/her of the themes to which he/she may proceed.

Monitoring the answers given. The system allows monitoring the answers given by students to end-of-topic exam questions.

Monitoring students in the learning process. The system prevents students from proceeding to another page before monitoring a page, hides activity answers, monitors the number of entrances of students and duration of remaining on pages, and determines the pages that are monitored, that are allowed to be monitored, and that are not allowed to be monitored.

Page monitoring level. The system determines the page monitoring levels (page study levels) of students as "Good", "Moderate", and "Bad" and prevents those students who have not reached the requested level from proceeding (The page monitoring level is calculated based on the number of entrances by students in pages and duration of remaining there).

Navigation. The system determines the pages which can be entered by students and directs them to such pages. It also provides navigational adaptation.

The Teaching Method Employed in the Study

The teaching method of the Web-based ITS used in the present study was implemented in the experimental process. This teaching method is programmed instruction, which refers to ordered or programmed arrangement of learning tools and materials to make students reach the related behavioral goals (Çağiltay & Göktas, 2013).

The principles which the programmed instruction is built upon are presented below.

Principle of small step. Topics are presented to a student through division into sub-topics. Topics are from simple to complex. The student proceeds to the work performed by the varying force after he/she completes the work performed by the constant force. The student has to achieve the passing grade in the end-of-unit exam determined by the teacher in order to proceed to a new unit. If this condition is not satisfied, the system does not allow the student to proceed to a new unit.

Principle of active responding. The Web-based ITS is a learning system based on the interaction between students and computer. Thus, there is a continuous interaction between the system and students. The system monitors students, addresses questions to check whether or not knowledge has been acquired, and ensures active responding by enabling students to answer such questions. It also contributes to active responding by giving instant feedback to the answers of students.

Principle of immediate confirmation. Immediate feedback (i.e., true or false and in red color) is given to students in regard to results. The Web-based ITS immediately reports as feedback whether the responses of students to activities and end-of-unit questions are true or false. The teacher can see such responses and feedback, too.

Principle of self-pacing. The Web-based ITS used in the study is an adaptive system and does not bring any limitation to students in the learning process. They may reach the lesson content whenever and wherever they want. This allows students who use the system to receive a free and individualized education.

Principle of correct answers. Whether or not the answers given by the students using the Web-based ITS are true is immediately reported to them as feedback. Students can re-answer by reviewing what they have done or the topics they have covered. If they cannot reach correct answers, they may obtain information by sending the teacher an e-mail or using social communication tools. Furthermore, the teacher sees the pages studied by his/her students as well as their responses to the activities. The teacher writes suggestions and comments as feedback so that students can find the correct answers.

The intelligence features of the system used in the study overlap with the programmed instruction. Although printed materials are used in the programmed instruction, instructional design theory is widely used in the computer environment. According to Jonassen (1996), computer-based teaching is a practice developed based on the programmed instruction.

Method

Scope

The present study involves the pre-tests, post-tests, and permanence tests of 26 students from the Mathematics Teaching Program, Department of Primary Education, Faculty of Education, Kastamonu University, who learned such Physics-I units as work, energy, and conservation of energy via a Web-based ITS.

Limitation

The study is limited to the pre-tests, post-tests, and permanence tests of 26 students using a Web-based ITS.

Significance

ITSs are regarded as future's teaching systems. It is considered that examining the influence of a Web-based ITS developed for contributing to physics education and making it effective, productive, and interesting may contribute to the related literature.

Study Group

The study group consists of 26 students from the Mathematics Teaching Program, Department of Primary Education, Faculty of Education, Kastamonu University, who are receiving the Physics-I course in the 2012-2013 academic year.

Research Model

“One-way repeated measures test”, which is a semi-experimental design, was employed in the study. After the students' knowledge of the lesson content was measured via the achievement test, which was developed by the researchers as a pre-test before the experimental procedure, the students were informed about the adaptive ITS named “Turkish Intelligent Tutoring System” (TURSOZ) developed by Karacı (2013). Then, they used the system online for four weeks. The achievement test was administered to the students as a post-test after the experimental procedure. The same test was conducted as a permanence test 45 days later following the administration of the post-test.

Data Collection Tool

The academic achievement test was developed on such Physics-I topics as work, energy, and conservation of energy. The achievement test comprising of 25 questions was administered to 35 students who had received the above-mentioned course before. Six questions that were found to have low reliability in item analysis were removed. Thus, the achievement test consists of 19 questions including concept and problem questions. The achievement test was administered as a pre-test, as a post-test, and as a permanence test to measure the knowledge levels of the students in the beginning, to determine the increase in their knowledge through the experimental procedure, and to see the permanence of such knowledge.

Data Analysis

The data obtained through the experimental procedure were analyzed via the one-way repeated measures test. Repeated measures are carried out to determine the difference between a categorical variable that has minimum three sub-dimensions and continuous variables (Pallant, 2011). The dependent variable of this study is a continuous variable. It is the progress scores of the pre-service primary school mathematics teachers receiving the Physics-I course. The independent variable, on the other hand, is a categorical variable. It is the tests performed in the experimental process (i.e., the pre-test, the post-test, and the permanence test). ω^2 coefficient was calculated to find the influence quantity of the difference statistic conducted.

Findings

The pre-test, post-test, and permanence test results of the experimental group were compared. Table 1 shows the mean scores obtained besides standard deviation values. The sphericity of the data was violated

through the Mauchly test conducted for identifying sphericity, which is one of the assumptions of repeated measures ($\chi^2(2) = 19.7; p < 0.05$). The degree of freedom was confirmed via Greenhouse-Geisser's sphericity coefficient ($\epsilon = 0.41$). It was found out that the use of Web-based ITSs makes a significant difference in teaching such units as work, energy, and conservation of energy to pre-service primary school mathematics teachers receiving the Physics-I course and ensuring the permanence of the knowledge acquired ($F_{(1.67, 32.05)} = 502.92; p < 0.05; \omega^2 = 0.89$). The omega square test, which was conducted to calculate the influence quantity, showed that the coefficient was 0.84. Thus, it can be said that Web-based ITSs have a big influence on teaching such units as work, energy, and conservation of energy to pre-service teachers and ensuring the permanence of knowledge acquired (Pallant, 2011). This influence quantity explains more than 25% of the total variance (Cohen, 1988, as cited in Field, 2005).

Table 1

The Pre-test, Post-test, and Permanence Test Descriptive Statistics of the Experimental Group

Test type	<i>N</i>	<i>M</i>	<i>SD</i>
Pre-test	26	23.88	6.62
Post-test	26	73.80	8.93
Permanence test	26	71.88	7.92

Figure 2 indicates the scores obtained in the tests, which are dependent variables, in the experimental process. The lessons received by the pre-service teachers within the scope of the units work, energy, and conservation of energy via the Web-based ITS had a big influence on their academic achievement scores. This technique led to an increase of 50 points in the achievement scores of the pre-service teachers. The permanence test, which was conducted 45 days later following the completion of the experimental process, demonstrated that the pre-service teachers had high scores and there was just a slight fall in comparison to the scores achieved by them in the post-test.

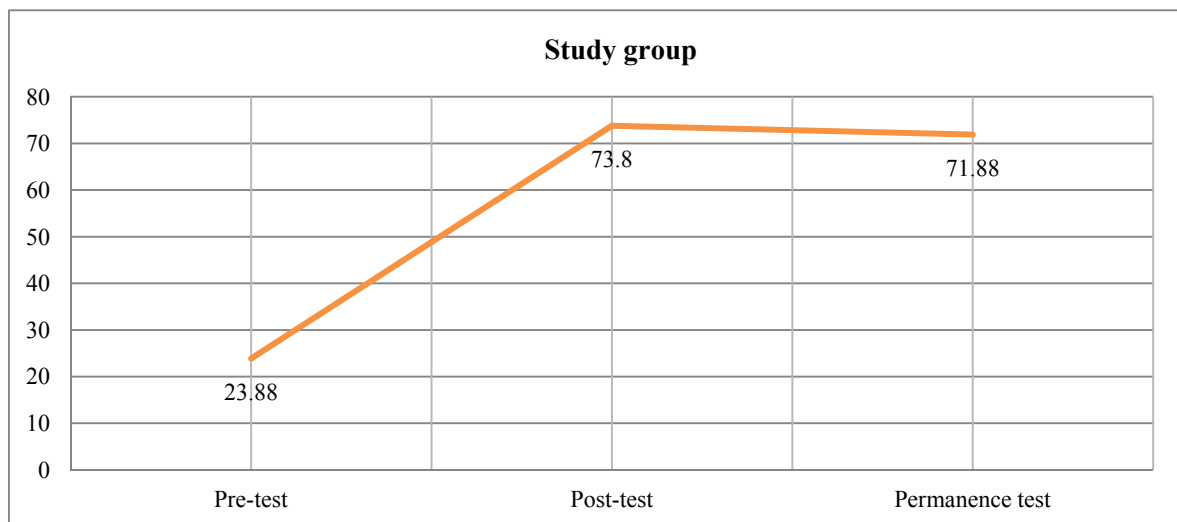


Figure 2. The pre-test, post-test, and permanence test scores of the pre-service teachers in the experimental group.

Based on the research findings, it was concluded that the Web-based ITS used in the study improves academic achievement of pre-service primary school mathematics teachers in such Physics-I units as work, energy, and conservation of energy and ensures the permanence of knowledge acquired in such units.

Discussion and Conclusion

Table 1 presents the arithmetic means of the pre-test, post-test, and permanence test scores obtained by the research participants as well as relevant standard deviation values. According to the arithmetic means, Web-based adaptive ITSs enhance achievement. In addition, the existence of a statistically significant difference between pre-test and post-test scores ($p < 0.05$) demonstrates that the use of a Web-based ITS for teaching such topics as work, energy, and conservation of energy has a positive influence on achievement.

Lack of any significant difference between post-test and permanence test scores shows that Web-based ITSs have a statistical ($p > 0.05$) influence on permanence. Figure 2 also shows that there is quite a big and statistically significant difference between pre-test and post-test scores. There is quite a small and statistically insignificant difference between post-test and permanence test results. Based on all these data, it is realized that Web-based ITSs improve academic achievement and ensure the permanence of the knowledge acquired.

Web-based ITSs can be used in physics education. The usage of these systems may provide advantages about time, space, and individual perception. These systems may also contribute to the research in this field and lessons taught in the classroom environment. Researchers may investigate the influences of similar techniques on different courses and topics in the future and make contribution to the literature in this way.

Web-based ITSs may be used for improving the quality of distance education. In distance education, it is quite difficult to monitor the study processes of students. It is teachers who monitor such processes in the case of in-class training. Web-based ITSs, which act similarly to teachers, may be used for monitoring these processes in distance education.

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