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Development of Web-Based Intelligent Tutoring (*iTutor*) to Help Students Learn Fluid Statics

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ABSTRACT

Fluid statics is one of the most difficult topics for students to learn. Formative assessment and remedial instruction can help students master the concepts. However, identifying students' challenges for formative purposes and facilitating remedial learning is not easy given to the number of students and variation of the problems encountered. An alternative solution to overcoming such problems is the use of web-based intelligent tutoring (iTutor). This research aims to develop and examine the feasibility and effectiveness of the web-based program iTutor. This research project consists of 3 steps, i.e., preliminary study, development, and examination. Three professors, 3 physics teachers, and 74 secondary students participated in this study. The instruments for collecting data included tests, questionnaires, and interviews. The questionnaire and interview data were analysed both quantitatively and qualitatively, while examination data were evaluated by means of an independent t-test. Expert judgment and trial field-testing data confirm the feasibility and effectiveness of using the iTutor program to improve students' mastery of physics concepts.

Keywords: formative assessment, intelligent tutoring (*iTutor*), remedial learning, fluid statics

INTRODUCTION

When learning physics, many students have difficulty either understanding the concepts or solving the problems. Some studies reveal that many students have particular difficulty understanding fluid statics. Oftentimes, students misunderstand the concept of Archimedes' Principle (Ünal and Costu, 2005; Yin et al., 2008; Bierman et al., 2003; Loverude et al., 2003; Wagner et al., 2013; Wong et al., 2010; Lima et al., 2014) and hydrostatic pressure (Loverude et al., 2010; Goszewski et al., 2012). Preliminary studies of eleventh-grade students in high school reveal the same results. The students' difficulty in learning this topic can cause them to fail to meet minimum standards.

One way to overcome the problem of student learning difficulties is to implement formative assessment and remedial teaching. Formative assessment can help teachers obtain information about students' learning progress (Bell and Cowie, 2002; Popham, 2008). This

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information is useful for students to organize their learning and for teachers to organize and carry out remedial instruction (Lambert and Lines, 2000). This coincides with the recommendation of the *Ministry of Education* No. 66 (2013), which states that students who do not achieve a minimum score should receive remedial instruction. Remedial learning helps students meet the minimum testing standard.

Formative assessment and remedial learning must be applied when learning physics. Because physics consists of many correlated concepts, if one concept is missed, it will be difficult to understand others (Ornek, 2008). Anderson (Chen, 2011) stated that to study effectively, students must organize and build on what they have already learned. This means that, whenever students do not understand a given topic, they should receive remediation in a timely fashion.

However, in the context of learning in Indonesia, the implementation of formative assessment and remedial teaching is not easy. Preliminary results from Kusairi (2012) revealed some difficulties of implementing formative assessment, including the large number of students in every classroom, the time needed to prepare formative assessment instruments, the specialised skills needed for its implementation, and the lack of developed automation systems to support its implementation. An interview with some physics teachers in a high school revealed that current remedial learning lacks adaptability, interaction, and timely feedback due to the high teacher-student ratio, which contributes to the lack of time teachers have to serve every student. Moreover, teachers have too many classes to maximize remedial learning (Jong et al, 2004; Lin, 2007). Implementing formative assessment requires real-time feedback from teachers, which is difficult without the support of adequate tools and technologies (Sorensen and Takle, 2005; Jahjouh, 2014).

Various preliminary studies show the effectiveness of web-based formative assessment. Heinrich et al. (2009) reported that electronic tools help manage assessment for learning (AFL) tasks and promote better time management. Nagel and Eck (2012) found that quizzes and feedback help students master the concepts. Self-assessment in the AFL also had a positive effect on student learning (Basnet et al., 2011). Kusairi et al. (2013) developed a model of web-based AFL that proved to be effective in helping students learn physics (Kusairi and Sujito, 2014).

Instead of using conventional remedial learning methods, we propose an online formative assessment and remedial learning program. The formative assessment and remedial learning use internet technology. Lin et al. (2007) reported that online remedial learning may raise students' learning achievements. They developed online remedial learning in a multimedia format. Demirci (2005) and Chen (2011) used a similar concept to apply online remedial learning to evaluate students' errors.

An excellent program for online assessment and remedial learning is intelligent tutoring (*iTutor*). *iTutor* is a computer-based learning system that can identify student's difficulties and choose the appropriate tutorial to match students' needs (Siemer et al., 1998; Jong et al., 2004). *iTutor* offers some advantages, e.g., (1) offering tutorial programs for an individual or large classes (Lin et al., 2007), (2) identifying students' difficulties in learning and providing quick feedback (Jong et al., 2004), (3) increasing the effectiveness and efficiency of students' learning (Butz et al., 2004), (4) helping students know their weaknesses and strengths (Myneni and Narayanan, 2012), and (5) helping teachers understand each student's development (Lin et al., 2007).

In recent years, various studies have evaluated the use of *iTutor* for learning physics and mathematics (GÜNEL and AŞLIYAN, 2009). Vanlehn et al. (2005) developed an *iTutor* program named *Andes* to increase students' problem solving strategies regarding the topic of force. Mitrovic et al. (2011) developed *Thermo-Tutor* to help students understand the concept of thermodynamics. In addition, Myneni and Narayanan (2012) developed a virtual physics system (*ViPS*) to overcome students' misconception of the Atwood machine.

Therefore, in this present study, we develop a valid and applicable *iTutor* program and describe its effectiveness.

METHODOLOGY

a. Research Model

This research study included three steps, i.e., (1) preliminary study, (2) development, and (3) examination. The preliminary study consisted of a literature study, field survey, and draft product designing. The development consisted of production, expert validation, and draft revision. The examination consisted of trial field-testing, final revisions, and quasi-experiments. The trial field-testing was meant to evaluate the quality and feasibility of the developed *iTutor* program. The quasi-experiment sought to determine the effectiveness of the web-based *iTutor* program on students' achievement.

b. Population

This study involved three physics lecturers as reviewers of the *iTutor* program, 3 physics teachers as *iTutor* users, and 17 students users who tested the *iTutor* program for 6 weeks. The examination included a quasi-experiment with post-test of control group design. The experimental class consisted of 30 students taught by using of *iTutor*, meanwhile the control class consisted of 27 students taught without *iTutor*. The sample class was X MIA 2 as the experimental class and X MIA 1 as the control class. The topic was fluid statics.

c. Data Collection Tools

The instruments for this research included a questionnaire, interview, and test. The questionnaires and interviews were utilized to collect data on the needs of assessment and remedial teaching undertaken by teachers. The questionnaire was also used to collect data on the validity of the model. The test was used to determine the mastery of the physics concept.

d. Data Analysis

The data obtained were analysed both qualitatively and quantitatively. The data were analysed by calculating the average score using four categories, i.e., excellent, good, fair, and poor. The interview result was descriptively and qualitatively analysed. The post-test score was analysed by means of an independent t-test.

FINDINGS

a. Product Specification

The developed product used the web-based intelligent tutoring system *iTutor*, which is made up of a *back end* for teachers and *front end* for students. Only administrators or teachers can access the back end of the program, which includes a problem bank, remedial notes, quiz management, account management system, and detailed information on student achievements. Students can access the front end of the program, which includes quizzes, feedback, manual solutions, remedial notes, and quiz reports showing their errors and scores.

The quizzes in *iTutor* are multiple-choice. The multiple-choice problems address concepts in fluid statics such as hydrostatic pressure, Pascal's Principle, and Archimedes' Principle. There are 62 problems in *iTutor*: 30 problems about hydrostatic pressure and Pascal's Principle and 32 problems about Archimedes' Principle. The problems are arranged based on the difficulty level. The remedial notes are provided to students that do not pass Quiz 1.

The procedures to use the *iTutor* program are: (1) students use their username and password to log-in to *iTutor*, (2) students can choose the lesson and topic they need, (3) students complete the multiple-choice Quiz 1, (4) students receive the Quiz Report containing their score, learning assessment, understanding level of material per indicator, and a link to the next quiz, (5) students who do not pass Quiz 1 will undergo remedial instruction before continuing to Quiz 2 with the same difficulty as Quiz 1. Quiz 2 measures students' understanding after undergoing remedial education as well as their problem solving skills. (6) Students who pass Quiz 2 can continue to Quiz 3 for additional enrichment exercises.

iTutor was created with HTML 5, PHP 5, and CSS 3. The database management is arranged by MySQL application. The web hosting has 1 Gb capacity and 10 Gb bandwidth per month. When cPanel web hosting is defined, *iTutor* was accessed online through www.itutoronline.net, which is accessible from various web browsers. Fig. 1, Fig. 2, and Fig. 3 present a sample display of *iTutor*.

Figure 1. *Quiz Display in the iTutor Program*

QUIZ REPORT 1

Student Name	:	Muhammad Rizal	Grade
Number of Correct Answers	:	5	71
Number of Incorrect Answers	:	2	
Time	:	10 min 23 sec	
Topic	:	Archimedes' Principle 	

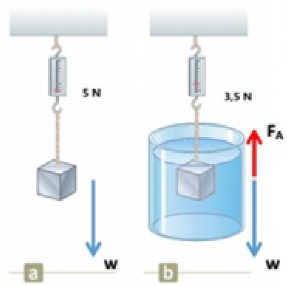
Indicator	Number of Problems per Indicator	Number of Correct Answers	Status	Solution	Remidial
Describing Archimedes' Principle	2	0	GOOD	see	see
Explaining instruments or phenomena related with Archimendes' Principle	1	0	GOOD	see	see
Explaining Archimedes' principle to determine the situations of an object in a fluid	2	0	GOOD	see	see
Explaining buoyant force on any object in a fluid using Archimedes' principle	2	0	need remedial	see	see
Applying Archimedes' principle to determine physical quantities of an object in a fluid	3	0	need remedial	see	see

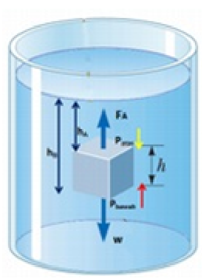
Figure 2. *Student's Quiz Report in the iTutor Program*

Describing Archimedes' Principle

Any object, partially or wholly immersed in a fluid, will experience a buoyant force. The magnitude of the buoyant force on that object always equals the weight of the fluid displaced by the object. This statement is then known as Archimedes' principle.
To better understand the concept of the buoyant force, consider a cube of solid material (a) suspended and then (b) completely immersed in a container of water (see figure). The reading on the spring scale after immersing the block in a container of water (3.5 N) is less than before (5 N). This is because the block experiences a buoyant force (F_A).

The net force in in Fig. (a) is $\sum F = w = mg$ where w is the weight of the block; m is the mass of the block and g is acceleration due to gravity. On the other hand, the net force in Fig. (b) is $\sum F = w - F_A$, where F_A is the buoyant force or Archimedes Force.





To evaluate F_A, we do the following analysis.
We know that the pressure P_{bottom} at the bottom of the cube is greater than the pressure P_{top} at the top by amount $\rho_{fluid}gh$, where h is the height of the cube and ρ_{fluid} is the density of the fluid. The pressure at the bottom of the cube causes an upward force equal to $P_{bottom}A$, where A is the area of the bottom face. The pressure at the top of the cube causes a downward force equal to $P_{top}A$. The resultant of the two forces is the Archimedes force F_A, where

$$F_A = \rho_f g h_B A - \rho_f g h_A A = \rho_f g h A$$

As we can see that hA is nothing but the volume of the immersed cube V_c, therefore

$$F_A = \rho_f g V_c$$

Figure 3. *Remedial Notes in the iTutor Program*

Teachers can see the results of every student's quiz in the back end of the *iTutor* program. In the first lesson, students who received remedial instruction for Quiz 1 show a better score than when they took Quiz 2, with the average increasing of 25%. The average student score for Quiz 1 and Quiz 2 was 46 and 71, respectively. Fig. 4 and Fig. 5 show the students' scores for Quiz 1 and Quiz 2, respectively, in the first lesson and the second lesson, respectively.

Based on the data from the expert validation form, *iTutor* offers excellent feasibility for students and teachers in terms of product quality, particularly regarding the display. The program is also feasible in terms of its content, construction, language, and isomorphism. The trial field examination of *iTutor* was conducted by 17 students in grade X SMA BSS and 3 physics teachers. The quantitative analysis found that *iTutor* demonstrates excellent feasibility in terms of usage, ability, and added value. The *iTutor* program was thoroughly revised after its validation by experts. The review from expert lecturers was used to refine the product as well as the multiple-choice problems. Therefore, *iTutor* can be used to provide remedial learning to help students understand difficult physics concepts, such as fluid statics.

Trial Class Examination

The trial class examination focused on the topic of fluid statics. The *iTutor* program was provided to the experimental class as homework. Meanwhile, the control class was given paper-based problems. The implementation of the *iTutor* program for fluid statics learning in the experimental class began with an introduction of the *iTutor* program to the students. Every student was given an account to access *iTutor* so they could complete the quiz individually or in a group. The use of *iTutor* in the experimental class was conducted twice, i.e., in the first lesson on the subtopic of Hydrostatic Pressure and Pascal's Principle and in the second lesson on the subtopic of Archimedes' Principle.

Table 1 presents the percentage of students who passed the learning indicators and clearly indicates that remedial learning helps students achieve the learning objectives.

Table 1. *Percentage of students who passed the indicators for Quiz 1 (before remedial learning) and Quiz 2 (after remedial learning) for the first lesson*

Indicator	Quiz 1	Quiz 2
Describing hydrostatic pressure equation (C2)	56%	75%
Explaining an instrument or phenomenon in correlation with hydrostatic pressure (C2)	88%	81%
Explaining hydrostatic pressure at different points in fluids (C2)	14%	70%
Applying the hydrostatic pressure equation in fluid statics (C3)	71%	71%
Applying the hydrostatic principle in fluid statics (C3)	50%	72%
Explaining an instrument or phenomenon as the application of Pascal's principle (C2)	0%	56%
Applying Pascal's Principle in a Hydraulic Jack (C3)	66%	72%

iTutor also helps students earn better scores. Fig. 4 reveals the escalation of the students' scores for Quiz 1 (before remedial learning) and Quiz 2 (after remedial learning). In the first lesson, the students' scores increase due to the remedial learning.

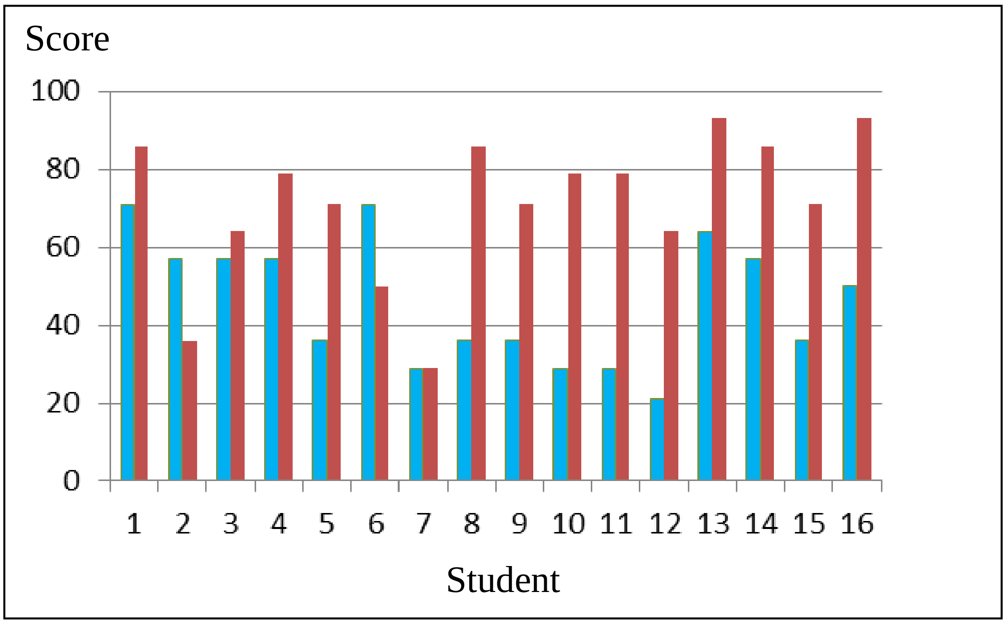


Figure 4. *Student Scores in Lesson 1 after Taking Remedial Learning (Blue: Quiz 1 score, Red: Quiz 2 score)*

Something similar also occurs during the second lesson. Students who did not attain the minimum score must receive remedial instruction. Afterward, the score increased 27% between Quiz 1 and Quiz 2. The average student scores in Quiz 1 and Quiz 2 were 53 and 81, respectively. Fig. 5 shows the diagram of students' score in Quiz 1 and Quiz 2 for the second lesson.

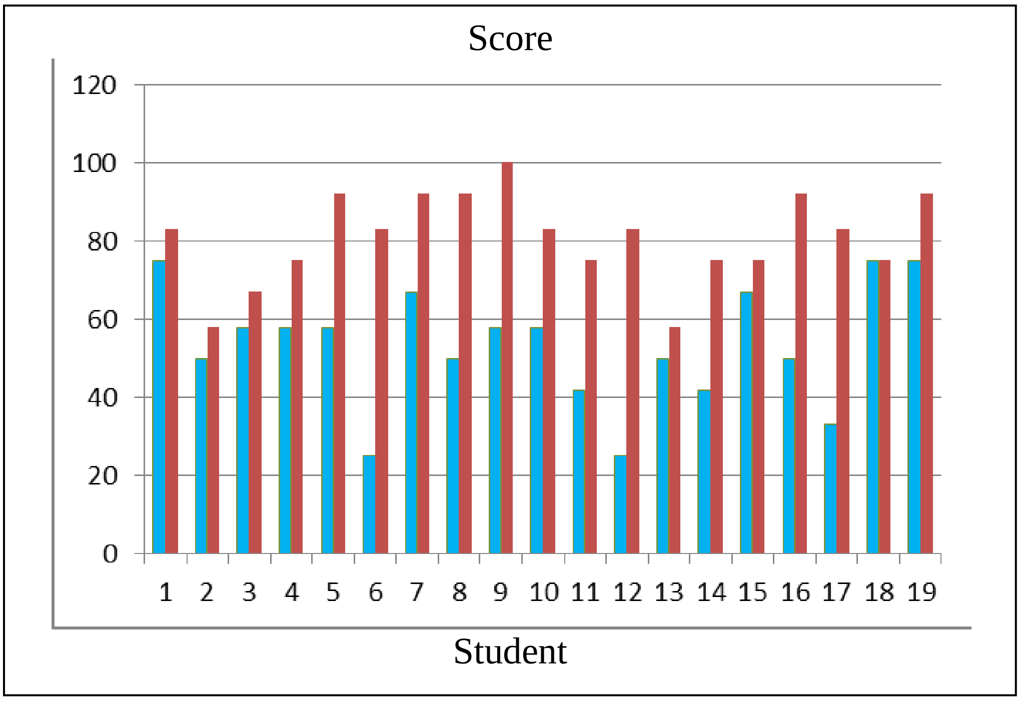


Figure 5. *Diagram of student scores in Quiz 1 and Quiz 2 for the second lesson after remedial learning (Blue: Quiz 1 score, Red: Quiz 2 score)*

Table 2 represents the percentage of students who receive remedial instruction for every indicator. The average score improvement from Quiz 1 (before remedial learning) to Quiz 2 (after remedial learning) in the second lesson is 30%.

Table 2. *Percentage of students for Quiz 1 and 2 after remedial learning in the second lesson*

Indicator	Quiz 1	Quiz 2
Describing Archimedes' principle (C2)	48%	97%
Explaining an instrument or phenomenon in correlation with Archimedes' principle (C2)	55%	84%
Explaining Archimedes' principle to determine the state of a matter in fluid statics (C2)	30%	66%
Explaining buoyant force for any matter in fluid according to Archimedes' principle (C2)	58%	68%
Calculating buoyant force for matter in fluid by applying Archimedes' principle (C3)	50%	89%
Applying Archimedes' principle to determine physical quantities in a fluid (C3)	69%	81%

A post-test in fluid statics made up of 25 multiple-choice problems focusing on hydrostatic pressure, Pascal's principle, and Archimedes' principle was then administered. Table 3 presents the t-test analysis result of the experiment and control groups' scores. There were 30 students in the experimental class and 27 students in the control class who completed the post-test. From the average post-test score, students who took *iTutor* received higher scores than those who did not. This can be inferred from the independent t-test results, in which the $t_{calculation}$ was 8.803, which was larger than t_{table} (t_{table} = 2.005) with a degree of freedom of 55 and significance of 0.05.

Table 3. Average student score in the experiment and control groups by means of t-test analysis

	Experiment Group	Control Group
Number of students	30	27
Average score	81.60	74.52

DISCUSSION

The final product in this study was a web-based intelligent tutoring program (*iTutor*) for the remedial learning of the topic of fluid statics. Teachers can use this program to provide their students with opportunities to complete online assessments and receive remedial instruction, particularly regarding the topic of fluid statics. *iTutor* can identify students' challenges, provide timely feedback, and give appropriate tutorial instruction based on students' needs. This is similar to some of the research and development carried out by earlier researchers (Zang et al., 2008, Lin et al., 2007, Jong et al., 2004, Myneni and Narayanan, 2012, Pierce et al., 2001, Osman, 2010). This program is efficient for teachers, as students can access it after school.

In contrast to previous forms of online learning that provided various links, adaptive navigation space, information spaces, and collaborative spaces (Seridi-Bouchelaghem & Sellami, 2001) that supported active learning (Morgil & Ural, 2006), our *iTutor* focuses on the role of formative assessment and remedial learning. Once students access *iTutor*, they will receive a number of test items. Furthermore, the computer will automatically analyse the test results and provide feedback that students can use to see which topics are difficult for them. This information is necessary for students to evaluate their learning, as well as for physics instructors to evaluate the learning strategy. Before the next series of tests, students can access appropriate remedial learning tools. In other words, *iTutor* provides remedial services to students according to their needs.

From the research results, it can be inferred that *iTutor*, in general, is a very effective program. The advantages of *iTutor* include: (1) its accessibility via various web browsers and internet-connected devices; (2) quick feedback and quiz results, including a report with the score, time, completion of every indicator, and a link to solutions and remedial notes, all of which can be saved in a pdf format; (3) the written solutions are clear and complete, including animations to correct students' misunderstandings about fluid statics; (4) on the back end, teachers can create problems and notes for remedial learning, manage course and meetings, add lessons and users, and view students' quiz reports; (5) there are 4 types of reports that can be saved in excel formats, i.e., students' scores, score per problem, percentage score per indicator, and answer of problem, all of which teachers can use to determine their students' abilities.

Using *iTutor* to learn fluid statics is effective in improving students' understanding via remedial learning. The average increase in student scores after taking remedial learning from Quiz 1 to Quiz 2 was 25% and 27% for the first and second lessons, respectively. Meanwhile, the average increase in students' mastery of the topics after remedial learning from Quiz 1 to Quiz 2 was 22% and 30% for the first meeting and second lessons, respectively. Hence, the quick feedback of remedial learning may increase students' understanding and comprehension of material. The average score of students who completed remedial learning with *iTutor* are higher than of those who did not. These results are consistent with those of previous studies (Klecker, 2007, Butz et al, 2004). In this study, the impact of *iTutor* can be evaluated based on concept mastery. It is, however, important to study the impact on other aspects, such as the meta-cognitive aspect (Shen & Liu, 2011).

CONCLUSION and IMPLICATIONS

Web-based intelligent tutoring (*iTutor*) has been successfully developed. *iTutor* focuses on the role of formative assessment and remedial learning. Validation and field-trial testing reveal that the *iTutor* program is feasible to apply. The examination results also indicate that *iTutor* can assist teachers in providing remedial instruction and can support students learning physics. According to the product development and implementation, the following suggestions can be proposed: (1) *iTutor* program can serve as homework for students, as students can use it individually after school without time or place limitations; (2) the report contains important information for students and teachers to evaluate students' challenges and achievement; (3) teachers can modify the problems, solutions, and remedial material in flash format for any desired topic; (4) a security system can be installed on *iTutor* to prevent a student from logging in with two different accounts; (5) the number of problems per indicator can also be increased.

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