TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 15, Özel Sayı, Aralık 2018

Journal of
TURKISH SCIENCE EDUCATION
Volume 15, Special Issue, December 2018

http://www.tused.org

The Use of Computer-Based Interactive Game to Make the Imaginary Logic of Structural Analysis More Real

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Received: 20.06.2018 **Revised:** 20.09.18 **Accepted:** 15.12.2018

The original language of article is English (v.15, n. Special Issue, December 2018, pp.1-12, doi: 10.12973/tused.10251a)

ABSTRACT

This study aimed to design an innovative learning media (i.e., Macromedia Flash program) for Structural Analysis subjects at Secondary Vocational Building Engineering School to improve students' learning outcomes. In the design process, the current study included such stages as defination, design, expert validation, pilot-test, and dissemination. The defination stage formulated subject's achievement indicators or competencies. The design stage included planning a design and then implemented it. Four experts validated the design. The pilot-test gave students a chance to make prior assesments for the designed products. At the dissemination stage , the interactive gaming mediawas conducted with one class at Vocational Building Engineering School. The results indicated that the developed instructional medias were feasible and effective in improving students' learning outcomes.

Keywords: Computer-based interactive game, learning media, structural analysis

INTRODUCTION

Structural analysis, which is an important subject for civil and building engineers, purposes to contain a proper strength, rigidity, and safety design. This subject consists of different loaded materials and their effects on the buildings. Through a structural analysis process, a comprehensive assessment ensures that deformations occur in a structure due to a maximum load limit in building standards. The structural analysis integrates such disciplines as mechanics, dynamics, and failure theories to compute the internal forces and stresses the designed structures. These integrated disciplines incorporate imaginary logic meaning only descriptions of some conditions instead of real objects. The characteristics of these materials require engineering students to have a kinesthetic learning style (Ictenbas & Eryilmaz, 2011), which enables them to catch the 'structural analysis' concept. The teacher needs more effort and time to help students understan[1]d the concept and achieve minimal competencies targeted

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© ISSN:1304-6020

Journal of Turkish Science Education. 15(Special Issue),1-12

by this subject. The successful implementation can be seen as an achievement indicator of the targeted learning, e.g., cognitive learning outcome(s). Some cognitive learning outcomes (e.g.,factual knowledge, cognitive skills, and met[2]acognitive skills) can be distinguished.

The success of a teaching-learning process depends on some variables, i.e., teachers, students, learning methods and learning medias, and learning facilities. Of these factors, teachers act as a main actor in the learning process and have a crucial role in the success of the learning process. Teachersplan a learning environment and then carry out their plans by arranging learning facilities, and tools and learning strategies. Hence, they facilitate students to grasp the subject's messages easily.

One way to afford students to understand the content of structural analysisis the game as a learning tool. Secondary high school students generally enjoy playing games and spend 12.2 hours a week for gaming (Statistica, 2017). The subject matter in a game is more interesting for students. Previous studies have used games in classes and reported their effects on student engagement and cognitive learning outcomes. Further, they have addressed that game playing achieves such varied goals as insights into economic processes, and understanding of a relationship between cause and effect (Huizenga, ten Dam, Voogt, & Admiraal, 2017).

Game, which can be utilized as an interesting learning media, attract students to learn the subject matter with enjoyment. Game, as a learning media, has a capability to make students feel more comfort and fun during the learning process, as well as boosting learning motivation (Fraser, Shane-Simpson, & Asbell-Clarke, 2014; Bjælde et al., 2015; Huizenga et al., 2017). Game-based learning engages students in actively developing their competencies and increases their retention levels of knowledge (Pedersen, Skyum, et al., 2016). Interactive games encourage students to actively involve in every learning process.

Game visualizes the content of imaginary logic in the structural analysis, and promotes them to easily understand. A combination of visual representations and interactive game allows students to obtain an intuition even for materials, which do not have any similarity to their daily life (Lieberoth, Pedersen, & Sherson, 2015). Game-based instruction is an excellent way to provide an authentic context stimulating reality and meaningful learning. To achieve the expected goal(s) of game-based learning, teacher needs to choose the best instructional game and find the right way at the right moment to interact students with each other (Huizenga et al., 2017).

The present study, focuses on a small-scale intervention in a structural analysis course at a secondary vocational school, intends to replaced traditional lectures with game-based learning (a structural analysis game) developed by the teacher and team. The following questions guide the current study: 1) How is the feasibility of an interactive computer-based game for the 'Structural Analysis' course? , 2) At which extent does game-based learningin the 'structural analysis' course make a contribution to enhance students' cognitive learning outcomes?

METHODOLOGY

This study conducted a design-based research (DBR) because it is an ideal research design for developing a game and a new educational technology (Koivisto et al., 2018). A group experts (a researcher, a game developer and a structural analysis' teacher) collaboratively worked and developed an interaction game as a learning media for the 'structural analysis' course at 10th grade in a secondary vocational building engineering school. The DBR followed several steps shown in Figure 1.

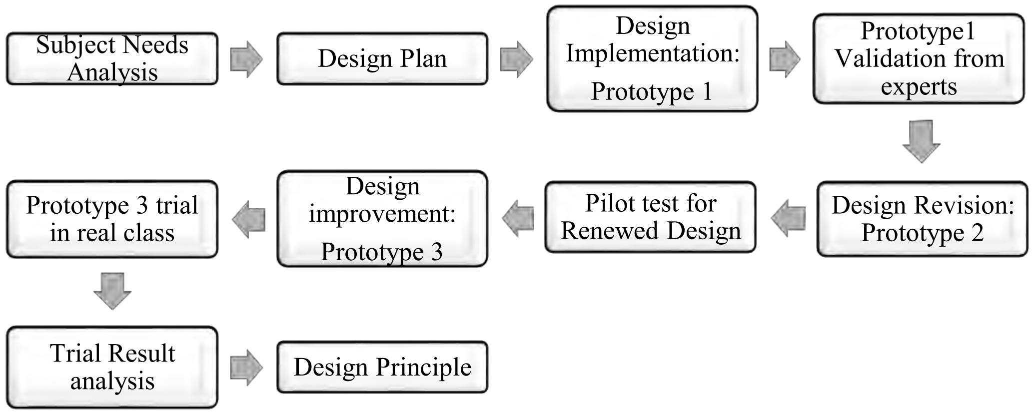

Figure 1. A flowchart for design-based research's steps

In the first step, the research team discussed the needs of subject according to the school's curriculum and its competency indicator(s). Then, team made a design plan consisting of every single material and inserted developed ones into the learning tools. The interactive game was later improved and for the design implementation step, and produced as a prototype 1 of learning media. Four experts (two learning media and two subject matter experts) validated the prototype 1. The prototype 1 was revised given the experts' feedbacks. Hence, prototype 2 was produced and pilot-tested with 10 students. In this process, the students were asked to fulfill a questionnaire about the design of learning media. Data obtained from experts' validation and pilot-test were in two kinds, namely qualitative data in the form of input improvements and quantitative data in the form of scores in the Likert scale. Qualitative data was used as a basis for learning media improvement. Quantitative data scores were then calculated by comparing the score with the maximum score. The percentage score obtained determines the feasibility of the product, with the provisions as in Figure 2 (Riduwan, 2012). Then, based on the results of the pilot-study, the research team made some improvements to generate prototype 3. Later, the improved design was tested in real class with 30 students. Through a pre- and post-test research design, the feasibility of the design was tested.

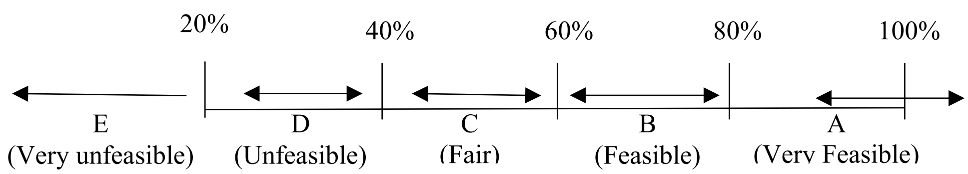

Figure 2. Scale of product feasibility

RESULTS

The results of each step of the design-based research are shown in this section.

a) A need analysis of the subject

Team's members firstly reviewed related curricula and documents (e.g., syllabus, existing learning plan, textbook, and student workbooks). Thereby, they identified the needs for the materials supporting the achievement of the structural analysis competency. That is, this subject consisted of two main materials, e.g., structure truss analysis including Cremona method, Richter method, Joint method, and Cullman method and mechanics of materials containing stress-strain and deflection. Then, the team observed the existing teaching-learning processes in the school. Their field observations pointed that a printed teaching material was the only available learning tool for theorical knowledge and questions in student exercises. Unfortunately, students attract less learning interest to the teaching material's writing and performance contents. Given these issues, the team decided that an interactive game would stimulate their learning motivations and create an enjoyable learning environment for the structural analysis subject.

b) Design Plan

For the design plan step, the team created a storyboard or a design sketch that describes the flow of the interactive game learning media. The flowchart of the interactive game learning media created in the design plan is displayed in Figure 3.

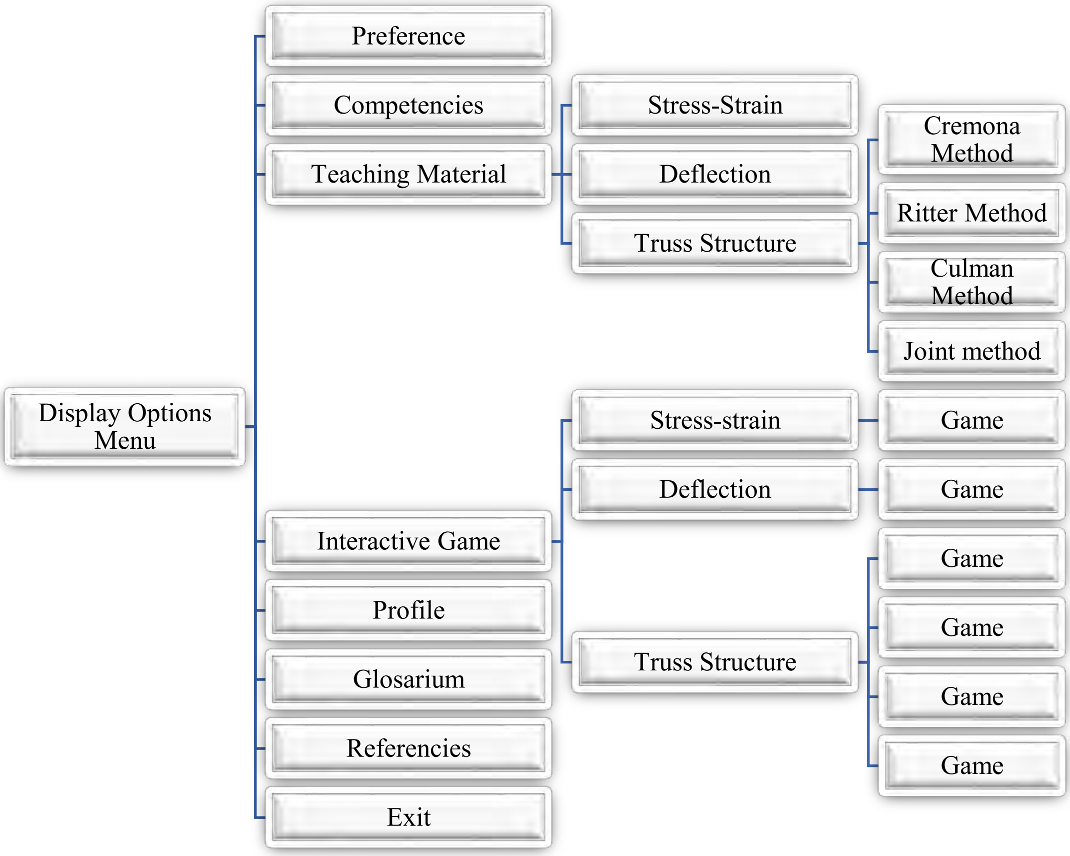

Figure 3. Flowchart of the interactive game learning media created in the design plan

c) Implementation of the Design Plan

This stage aimed to build an interactive game learning media via appropriate softwares that deployed macromedia flash for the learning media, and Photoshop for editing background pictures and media's button. The developers tried to make learning media easily understandable and interesting. The front page of the learning media is displayed in Figure 4.

Figure 4. The front page of the learning media

d) Validating the Learning Media

Four experts (Two subject-matter experts, a civil engineer, a vocational building engineer) checked and validated the prototype 1 of the interactive game learning media.. The subject-matter experts focused on its instructional aspects and suggested several revisions/improvements:

a. A need to add a 'subject matter' explanation at the beginning of the learning material
b. Dividing the subject matter into several parts to facilitate the material search
c. Completing all procedures for cremona method in the game.
d. Making test questions simpler.
e. Addition an interesting animation into the learning material.
f. Giving an appreciation after completing each stage of the game.
g. Deepening the material, and adding the real structure examples to enable students have a better idea of the discussed constructs.

After revising the prototype 1, the experts scored the revised version of the game by responding a 19-item questionnaire (maximally 95 points -- 5 point per an item) on the instructional aspects of the learning material. The percentage of the subject-matter experts' scores are shown in Figure 5.

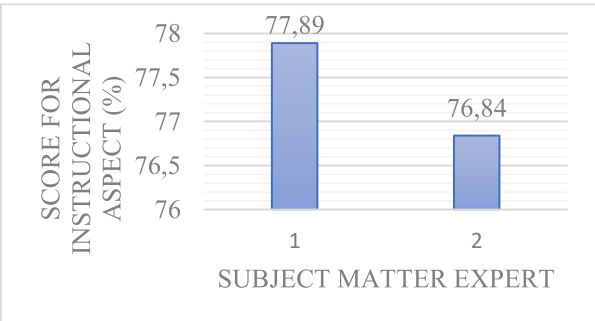

Figure 5. Subject-matter experts' scores for the instructional aspects of the learning material

Two 'learning media' experts (one from an educational quality institution and one from the IT center in Indonesia) reviewed and offered some subsequent revisions:

a. Creating a learning media facilitating student understanding of a material by avoiding the use of animation that would threaten student concentration
b. A need for consistency in content, terminology and/or display (template)

c. Using a customizable background sound by considering the type of audio and visual lessons.
d. Using a backsound fostering students to view the material instead of listening to the songs.
e. Employing varied assessments methods to measure high-order thinking skills and learning outcomes/competencies.
f. Ensuring button consistency (home, next, previous)
g. Illustrating workmanship in the form of the first animation.
h. Including instructions/manners of the material if required

Based on their suggestions, the team revised the design by improving the 'button and navigation' consistencies. Adjusting type of the game to the given problems afforded students to think about problem solving.
Media experts responded a 24-item questionnaire (15 for Software Engineering and 9 for Visual Communication -- maximally 120 points). Their judgment scores are presented in Figure 6.

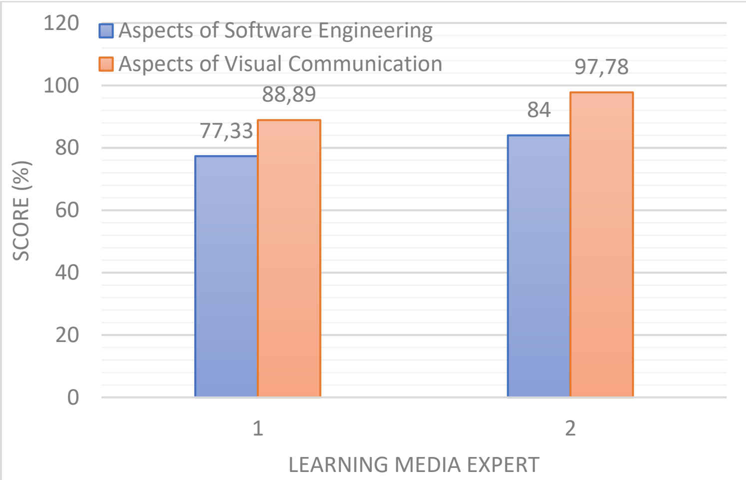

Figure 6. The learning media experts' judgment scores

e) The pilot-test

The last version of the learning media was pilot-tested with 10 students from 10 grade of Building Engineering Department at a secondary vocational engineering school in Indonesia. The pilot-test purposed to get a prior assesment for the designed products. A 31-item questionnaire (14 for the design of the instructional media and 17 for the material conformity) in Likert scale used to gather students' assessment related to the learning media. Besides the closed questionnaire, students give written suggestions for the designed product. The main suggestions appear from the pilot-test were a need for inserting more animations into the media that attracts student's interest and enriching the types of the game to minimize student boring.

The pilot test resulted 561 point for the instructional media, while the material conformity resulted 595 point. The maximal point for both categories was 850. Figure 7 shows the results of the pilot-test in percent. From the results of the pilot test it was concluded that the media developed was in the feasible category.

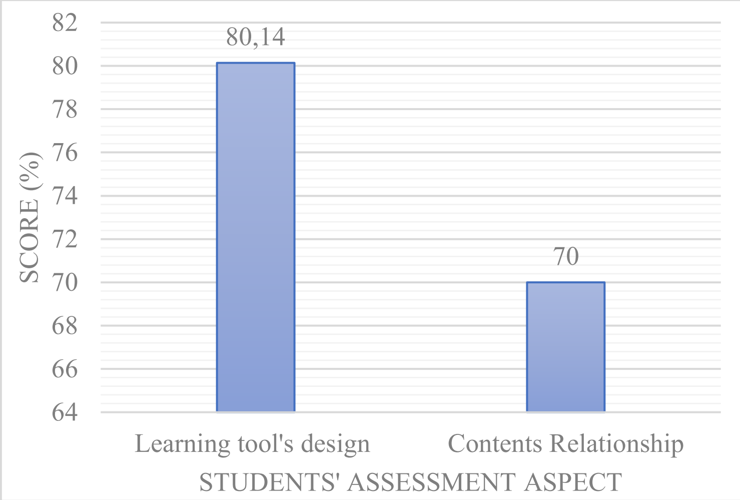

Figure 7. Grade 10 students' assessments of the pilot-test

f) Real study

After revising the learning tool in regard to the pilot-test's results, the revised version was implemented to 30 students from grade 10 in the 'structural analysis' course at a vocational building engineering school. After completing the interactive game learning media, the students were asked to respond a 31-item questionnaire (14 for the design aspects of instructional media and 17 for the material conformity). Their assessment scores are shown in Figure 8. Base on the full class test result it was concluded that the learning tool pointed to a feasibility category (73.9%).

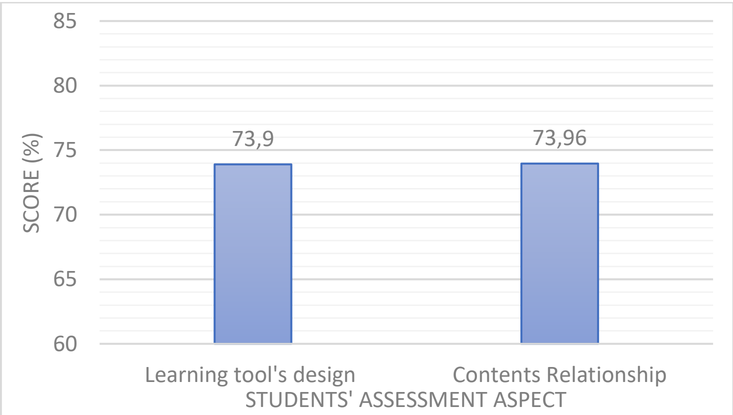

Figure 8. The students' assessment scores after the real study in full class

g) Student's learning outcome(s)

Students' learning outcomes obtained from the pre test and post test with a passing grade of 78. Their learning outcomes in pre-test and post-test is revealed in Figure 9.

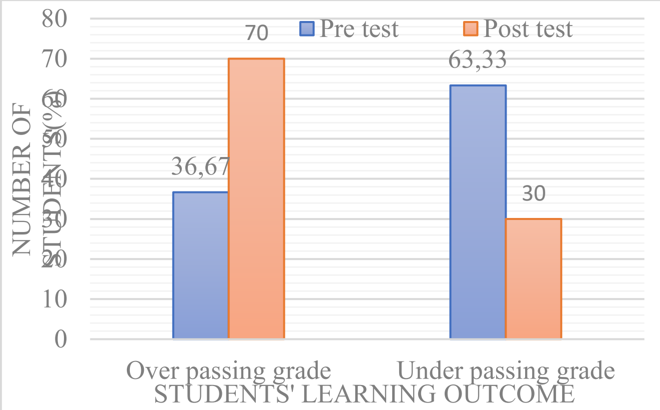

Figure 9. Students' learning outcomes in pre-test and post-test

h) T-Test

T-test was used to measure the extent to which the learning design improved student achievement. That is, t-test compared their learning achievement levels before and after the use of the learning design product. This comparison used the following t-test formula:

$$t = \frac{\mu 1 - \mu 2}{\sqrt{\frac{S1^2}{n1} + \frac{S2^2}{n2} - 2r\left(\frac{S1}{\sqrt{n1}}\right)\left(\frac{S2}{\sqrt{n2}}\right)}}$$

$\mu 1$: The average value of the first test (Previous work system)
$\mu 2$: The average value of the second test (New work system
S1: First standard deviation (Previous work system)
S2: Second standard deviation (New work system)
r: Correlation between the groups
n1: number of data from the first test (Previous work system)
n2: number of data from the second test (New work system)

Based on the results of the pre- and post-test, the team hypothesized the followings:
Ho = Pre-test was at least equal to post-test
Ha = Pre-test was lower than post-test
Ho = $\mu 1 \geq \mu 2$
Ha = $\mu 1 < \mu 2$

It was the left-side t-test because the alternative hypothesis was "Lower", and t value was:

$$t = \frac{65{,}33 - 76{,}03}{\sqrt{\frac{129{,}56}{30} + \frac{74{,}23}{30} - 2.0{,}57\left(\frac{11{,}38}{\sqrt{30}}\right)\left(\frac{8{,}62}{\sqrt{30}}\right)}}$$

$t =$ -2,20

The foregoing t value, which compared with the distribution of t-test with the degrees of freedom (df) = 29 for the one-party test with 1% error rate, the adjusted t value was 2.462. If the calculated t falls into the acceptance of Ha, Ha states that post-test is better than pre-test. The aforementioned t value (-2.20) accepted Ha or rejected Ho. That is, there was a significant difference between the students' learning outcomes in the pre- and post-test since the post-test value was higher than the pre-test.

DISCUSSION

The imaginary logic of the ‘structural analysis’ subject is more realistic in that the described subject material (Figure 10) was employed animation pictures and several varied types of the interactive games were presented. To cultivate basic understanding of structural analysis, the first game in the learning media was a crossword puzzle game (Figure 11). The crossword puzzle, which appeared in the Sunday New York World in 1913, is an old game (Ntoa, Adami, Prokopiou, Antona, & Stephanidis, 2011). This joyful game has been used in education since 1929 ((Schafer & Behymer, 1992). Constructivist learning theory underpins the use of crossword in learning process. That is, students manipulate learning activities to construct an understanding of new knowledge ((Mergel, 1998).

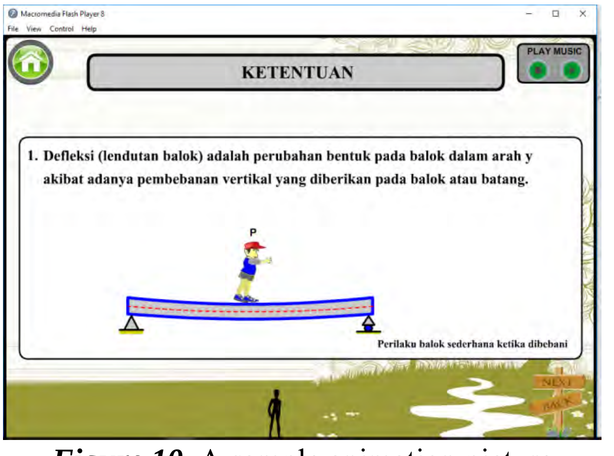

Figure 10. A sample animation picture

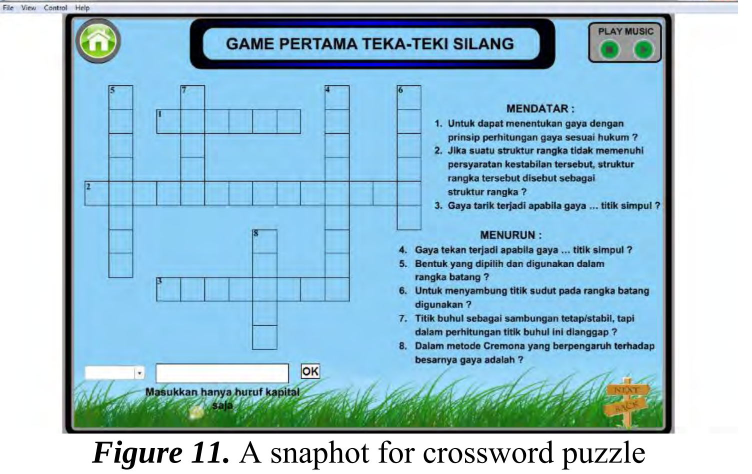

Figure 11. A snaphot for crossword puzzle

The second kind of game (an individual true or false game) on the basic understanding and procedures in the Truss Structure contained the learning media design (Figure 12). The educational true or false game could improve students’ learning motivations (Amalia, 2015). Students’ interests and motivations towards a lesson will enhance their conceptual understanding and trigger their memories (Jumaiyah, 2017).

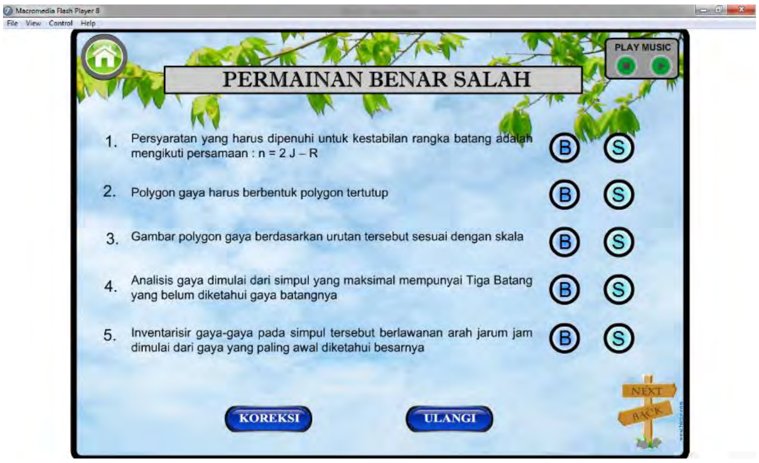

Figure 12. The true or false game

The third type of game (Click and Drag Game—see Figure 13) intended to helpstudents understand the direction of force and solve the truss structure analysis using Cremona method. Students clicked the selected line or direction of the line and then dragged it into the appropriate place on the structure. The Click and Drag game through enactive, iconic, and symbolic representation modes is in a parallel with Bruner's learning theory . In other words, students do the game, see a picture or image, and use some symbols (Bruner, 1966).

Figure 13. The Click and Drag Game

The team's observations of the design pilot-study and full class test stages indicated that the students were more interested in the game-based IT learning media. The students' learning enthusiastics were activated by the game-based interactive learning media. The results from the real-study showed that this game-based interactive learning media improved the students' learning outcomes. Although they were not at satisfactory level, they at least resulted in better student learning outcomes.

CONCLUSION

In light of the results, the current study reached to the following conclusions:

1. The expert judgments in the presented study states that this game-based interactive learning tool is worthy to be used for the whole class and individual learning.

2. Because the percentages of the student achievement score in the pre- and post-test were 36.67 and 70.00 respectively, it can be deduced that the learning media has a potential to use in classes. As a matter of fact, adjusted t-test value (2.462) supports this knowledge claim.
3. Students could independently operate this interactive learning tool to learn independently. This interactive game does not need to be installed. That is, the program only need to be copied and opened. The interactive game within the learning media makes its appearance and presentation appeal, and helps students comprehend any material change.

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