The Development of the Basic Programming Educational Game using the Instructional Game Model

C Agustina¹ and R Wardani²

¹, ²Electronics and Informatics Engineering Department, Graduate School, YSU
Jalan Colombo No 1, Caturtunggal, Depok, Sleman, Yogyakarta, 55282, Indonesia.

E-mail: candra.agustina2016@student.uny.ac.id

Abstract. While educational games can significantly affect students’ motivation and are considered more effective utilized in the material delivery, some scholars suggest that integrating the educational game (EG) design and learning model will be more effective in improving the students’ attention, relevance, confidence, learning, and satisfaction. This paper describes the development of an EG for Basic Programming integrated with the Instructional Game (IG) learning model. The EG development follows Luther’s six development stages, namely (1) concept, (2) design, (3) material collecting, (4) assembly, (5) testing, and (6) distribution. The respondents of this study were Grade X students of some Vocational High Schools in Yogyakarta. The Data were collected by observation and questionnaire. Quantitative descriptive technique was employed in the data analysis. The results of the concept, design, and material collecting stages show that the storyboard of the developed game should cover the pages for the splash screen, home, level selection, level 1, game instruction, Core Competencies and Basic Competencies (KI-KD), game information, feedback for correct and incorrect answers, instruction video, score, and the game over notification.

1. Introduction

Research on learning media is significant in the field of education because learning media act as important features in the learning process. This is in line with what was conveyed by the Minister of Education and Culture Muhadjir Effendy in the Regional Symposium on Learning Technology Development. He states that learning media act as the important aspects needed in promoting the quality of education in Indonesia. Learning media play an important role as that of learning method because when a specific learning method applies, certain learning media need to be used in integration with the learning process and adapted to the learning condition [1].

Based on the observation done in several Vocational High Schools (VHSs) in Yogyakarta, 81% of the students had trouble in Basic Programming. Observation results show that the factors contributing to such difficulties included their unfamiliarity with the Basic Programming materials (19%), difficulty in understanding Programming Algorithms (23%), difficulty to imagine the logic or process for developing programs (35%), lack of practice (7%), and unclear delivery of the materials (16%). As this course requires students to understand the Algorithm materials that are relatively new and rely on the ability of a careful mindset to study the Algorithm steps in the program development, some of the students still had problems in understanding the materials. Thus, it is necessary for the students to understand the basic concepts of Algorithms so that in the future they can apply those concepts into more complex programs.
In addition to the students’ difficulty, the data on the students’ motivation in participating in the Basic Programming lessons were also collected. The students’ motivation in this course subject was relatively low, indicated by 84% of students stating that they were less motivated and 79% of them felt bored when attending the lessons. Students got bored during the learning process as it lacked of variation (35%), the delivery of material was less interesting (21%), the duration of the lesson was too long (12%), and they did not like the lesson because the materials were difficult to understand (33%).

Concerning the students’ learning achievement, the success of learning in the 2013 Curriculum is assessed based on the four aspects of competence, namely knowledge, motivation, skill, and attitude. However, the observation results show that the students’ knowledge was still low. This is indicated by the number of students failed to achieve the minimum criteria of mastery learning (KKM) accounted for 79% and as many as 81% of students faced the challenge of Basic Programming materials. The students’ skill on the Basic Programming was also low, indicated by 44% of students could not develop the computer programming logic in the form of flowcharts, pseudocode, or natural languages, and that 37% of them was less capable to perform so. Moreover, 47% of students were unable to use Programming Algorithm to solve problems and 33% of whom told they were less capable of doing so. As many as 49% were also unable to use Branching Algorithm to solve problems and 35% said that they were less capable to do so. As many as 53% of students were unable to use Loop Algorithm to solve problems and 30% stated that they were less capable in doing so.

Observed in terms of the students’ attitude during the learning process, their enthusiasm in learning was still low. It can be seen from their participation, namely students were silent when they did not understand the materials taught. Besides, the students’ curiosity about the learning materials was also low. In the normal lessons, the materials of Basic Programming were usually delivered by lecturing and later the students were required to answer some practical practice questions. Such teaching-learning sequences run throughout the weeks without any variations so that students felt bored and unmotivated. Furthermore, the media used in the learning process were less effective and less attractive. Based on these phenomena, it is necessary to have innovative teaching-learning media to increase the students’ motivation and promote the students’ knowledge and skills of Basic Programming.

One of the solutions proposed to make learning more interesting and motivating is by using games as a learning technique. Some references that underlie the need for the use of games in the learning process, among others, suggest that games can eliminate boredom and provide challenges to solve in a fun atmosphere [1]. Furthermore, using games as a learning medium functions to (1) introduce students the use of computer technology, (2) provide lessons to obey directions and rules, (3) train the use of motor nerves and spatial skills, (4) make learning more entertaining and fun, and (5) provide a means to think, speak, and interact in new ways [2]. EGs can also provide innovative ways of learning by (1) providing interactivity that can stimulate learning, (2) enabling participants to obtain new knowledge, increasing curiosity and challenges that can stimulate learning, (3) equipping students with knowledge about technology; (4) assisting them to develop skills in the IT, (5) acting as a means of simulations; and (6) providing entertainment as in the childhood [3].

Moreover, the game approach is more effective in delivering material and more motivating than do the non-game ones. It supports that computer EGs can be used as effective and motivating learning techniques [4]. However, in the process of developing EGs, integration amongst appropriate learning models is needed so that learning can be more effective. Based on the survey conducted by Microsoft through the Microsoft Asia EduTech Survey 2016 involving nearly 200 instructors from 18 countries in the Asia Pacific including Indonesia, three main challenges were found in the application of technology in the world of education. They are, fistly, the problem of training in the application of technology in
the world of education (53%), secondly, the cost problem to facilitate the application of educational technology (51%), and lastly, the technology integration with the school curriculum (46%).

These also propose that the development of EGs should be integrated with the curriculum and pay attention to the aspects of learning and ways to improve the students' knowledge, motivation, and skills in the learning. Besides, the games should also be integrated with the appropriate learning models. One learning model that fits the EGs is called as the Instructional Games (IG). This is a computer-based learning model that uses EGs as a tool in the learning process. IG comprises of games designed to enhance learning and governed by instructions to reduce the rigid teaching and learning processes so that the regimens become more flexible [5].

Based on the problems described above, there needs to be a solution to improve the students' knowledge, motivation, and skills in Basic Programming. In this context, the researchers decided to develop computer-based learning media in the form of an EG that are integrated with the IG learning model. It is expected that the students can be more interested in learning the Basic Programming and that the effective learning process may occur.

2. Research Method

This is research and development (R & D) with the development model of Luther’s consisting of six stages, namely: concept, design, material collecting, assembly, testing, and distribution. The development procedures carried out in the study are as follows. (1) The stages carried out in the concept include determining the purpose of the application and determining the concept of the games. (2) The design stage comprises making detailed specifications regarding the application material requirements. (3) In the material stage, the material collecting was carried out in accordance with the students' needs. (4) The assembly stage is the stage of creating the game content. (5) The testing phase will be carried out by running the EG and observing whether any errors occur. The first phase of this test is called the Alpha Testing. The test should be carried out by material experts and media experts. Later, the Beta Testing should be carried out by involving the end users, namely the Grade X of VHS students and teachers. (6) The distribution phase refers to the dissemination of the educational game to the students and teachers of Basic Programming subject to serve as a supporting tool in the learning process.

3. Results and Discussion

This paper emphasizes on the design stages of Basic Programming EG integrated with the IG learning model. The design stages in the EG development are very important because they need a careful planning to integrate the elements of learning in the game. In addition to motivating students through the games, the purpose of the EG is to involve students in the activities that not only meet the psychological needs provided by play experience, but also support the cognitive processes and learning contents by making learning relevant and authentic in context. In short, the EG designers should try to make the computers and video games motivating in order to attract the students' interest, improve learning, and achieve the instructional goals [6].

3.1. Results

The results of the concept stage are the concept aspects of the EG, its content and model. Meanwhile, the results of the design stage are the EG storyboard. The following are the concept aspect, content, model, and storyboard of the EG.
Figure 1. The Aspects of the Educational Game

Based on the concept of the EG aspects in Figure 1, the content design was carried out to find out the application of these aspects in the educational game content. The results of the design of the EG content are described in Table 1.

Table 1. The Results of the Design of the Educational Game Content

| No | Aspect | Aspect Components | Description | Content/Application in the Game |
|----|--------|-------------------|-------------|---------------------------------|
| 1  | Knowledge | Student/user understands the use of data in Algorithm and the concept of Programming Algorithm | The game enable the student/user to understand the data usage in Algorithm and the concept of Programming Algorithm | Quiz (multiple choice, true/false, ordering stages) |
|    |         | Student/user understands the structure of Algorithm and analyzes data in Loop Algorithm | The game enable the student/user to understand the structure of Algorithm and analyzes data in Loop Algorithm | Quiz (multiple choice, true/false, ordering stages) |
| No | Aspect | Components | Description | Content/Application in the Game |
|----|--------|------------|-------------|--------------------------------|
|    | Algoritm and analyzes data in Branching Algoritm | Branching Algoritm and analyze its data | Quiz (multiple choice, true/false, ordering stages) |
|    | Student/user understands the structure of Algoritm and analyzes data in Loop Algoritm | The game enable the student/user to understand the structure of Loop Algoritm and analyze its data | |
| 2. | Motivation | Attention | Strategies to arise and maintain the student’s curiosity and interest:  
- Motivate the student by promoting their curiosity and interest in the content or learning context through the use of the Instructional Design.  
- Attract and direct the student's attention to concentrate on the visual features displayed or those accompanying the text on the subject matter. | The game’s immediate visual appeal is raised, rewards for the highest score/point are given |
|    | Relevance | Strategies suit the students’ needs, interest, and motivation.  
- Students are more motivated as the learning objectives are clearly stated and aligned with their interest. | The learning objectives suit the subject’s Core Competencies and Basic Competencies (KI-KD) |
|    | Confidence | Strategies help students develop positive expectations for success.  
- Learners are more motivated when challenges are balanced in such a way that the learning process is not too easy and boring, or so difficult that success seems to be impossible. | Students’ challenge is on the right answer and limited time. There will be a minus point/score for the wrong answer. |
|    | Satisfaction | Strategies provide extrinsic and intrinsic reinforcement for trials.  
- Learners are more motivated when rewards are given for actions that are carried out correctly. | Point/score, reward (digital badge) |
| 3. | Skill | Student uses Programming Algoritm to solve problems | The game trains the student/user’s skill to apply Programming Algoritm in solving problems | Quiz/Game (type: ordering/dragging and dropping/creating algorithms in natural) |
| No | Aspect | Aspect Components | Description | Content/Application in the Game |
|----|--------|------------------|-------------|---------------------------------|
|    |        |                  | The game trains the student/user’s skills to use Branching Algorithms in solving problems | Quiz/Game (type: ordering/dragging and dropping/creating algorithms in natural language, pseudocode, and flowchart) |
|    |        |                  | The game trains student/user’s skills to use Loop Algorithms in solving problems | Quiz/Game (type: ordering/dragging and dropping/creating algorithms in natural language, pseudocode, and flowchart) |
| 4  | Attitude| Increasing the students’ curiosity about the materials | The game increases the students’ curiosity about the materials | Game/quiz contents are made as attractive as possible to improve the students’ interest in the learning material |
|    |        | Increasing the students’ enthusiasm in the learning process | The game increases the students’ enthusiasm in the learning process | There will be a reward for the students with the highest point/score |
|    |        | Increasing the students’ active participation in the learning process | The game increases the students’ active participation in the learning process | The game challenges are made as attractive as possible |
| 5  | Instructional Games | Objective | Each game must have a goal, which is the predetermined learning goal. In some instructional games, goals are identical with the expected score achievement. | Goals/missions, score achievement targets |
|    |        | Rule | There are rules/instructions on what can or cannot be done by the student/user/player. These rules can change as long as they avoid weaknesses that occur or even to make the game better. | Game rules/instructions |
|    |        | Competition | Players attack the opponent, against themself and the opportunity or time set. | Players act against the time set. The competition presents scores between students. |
|    |        | Challenge | Challenges are designed so that the game becomes meaningful for the players. Difficult lessons can be used as challenges in the educational game. | Students’ challenge is on the right answer and limited time. There will be a minus point/score for the wrong answer. |
| No | Aspect | Description | Content/Application in the Game |
|----|--------|-------------|---------------------------------|
| 1  | Fantasy| Games often depend on the imagination developed to motivate players. | The fantasy of the game is in the form of the relationship between the client and programmer. |
| 2  | Safety | The game provides a safe way to deal with real dangers such as in war games. | Safety in playing games |
| 3  | Fun | Almost all games are entertaining, and games in learning play a role as motivators | The game is designed for fun |
| 6  | Educational Game | The game design aspect consists of usability, multimodal, and fun.  ➢ The usability aspect is that the educational game is considered useful when giving satisfaction to the players, effective and efficient in achieving the stated goals.  ➢ The multimodal aspect is the game’s combination of several media such as texts, graphics, videos and audios, and the player's ability to interact directly with these content and receive the appropriate feedback.  ➢ The fun aspects are that the educational game is designed for fun and entertaining students when playing. | The game is user friendly, easy to learn, and is useful to help the students’ learning |
|     | Pedagogy | The aspects of pedagogy consist of learning outcomes, self-learning, and problem solving.  ➢ The aspects of learning outcomes are that the game must be designed in accordance with the education domain and include the appropriate learning technique to ensure that the game will produce the desired learning outcomes.  ➢ The aspect of self-learning is defined as the extent in which the educational game is designed to support the | Learning outcomes: the game assesses students’ understanding, motivation, and skills through scores. |
|     |         |                                                                        | There are rules of the game, instruction videos or game tutorials, and help menus so that the |
| No | Aspect | Aspect Components | Description | Content/Application in the Game |
|----|--------|-------------------|-------------|--------------------------------|
| 1  | -      | -                 | independent learning by playing and assessing their own performance. | game can be used for independent learning |
|    |        | ➢ The problem solving aspect of the game is that the game is designed to stimulate the minds of the student/user and allows them to solve problems by interacting with the materials and in-game tasks. | Quiz/game |
|    | Learning Content Modelling | The aspect of learning content modelling consists of syllabus matching and scaffolding. | Learning materials and objectives are adjusted to the syllabus. |
|    |        | ➢ The aspect of syllabus matching is that the material in the educational game is adjusted to the material stated in the syllabus. | instruction videos or game tutorials and help menus |
|    |        | ➢ The aspect of scaffolding is that students are given a number of assistance in the early stages of learning and the responsibility for learning. Such assistance can be in the form of instructions, warnings, encouragement, examples, and actions that allow students to learn independently. | |

After designing the EG contents above, its design model was created and adjusted to the aspects of knowledge, skill, attitude, motivation, and the characteristics of instructional games and educational games. The educational game design can be seen in Figure 2.
After the educational game content and design, the game’s storyboard was designed. The storyboard serves to describe the design of each page in detail to facilitate the development stages of the EG. The storyboard of the educational game can be seen in the following table.

**Figure 2. The Educational Game Design**

**Table 2. The Educational Game Storyboard**

| No | Page  | Design | Description |
|----|-------|--------|-------------|
| 1. | Splash Screen | - The game logo with the zoom animation  
- No music or sound  
- Time: 3 seconds, then go to the home page |
| 2. | Home | - Game logo  
- *MULAI* (Start button): go to the level selection page  
- *PETUNJUK* (Hint button): go to the instruction page  
- *KI/KD* (*KI/KD* button): go to the *KI/KD* page  
- *KELUAR* (Exit button): exit the application  
- Information button: go to the information page  
- Sound button: to set the game sound (on/off) |
| No | Page | Design | Description |
|----|------|--------|-------------|
| 3. | Level Selection | ![Diagram](image1) | - *Home button*: go to the home page  
- *Petunjuk button*: go to the instruction page  
- *Sound button*: to set the game sound (on/off)  
- The text/menu: *PILIHAN LEVEL*  
- Game logo  
- Buttons for Level 1 – 9: go to the each level of game |

| 4. | Level 1 | ![Diagram](image2) | - Home button  
- *Petunjuk button*  
- Sound button  
- The text/menu: Level  
- Score  
- Question number  
- Life animation  
- Problem/question  
- Space for answer  
- Answer choices  
- OK button: to check the answer  
- The game is the drag and drop |

| 5. | Petunjuk (Hint) | ![Diagram](image3) | - Home button  
- *Petunjuk button*  
- Sound button  
- The text/menu: *PETUNJUK*  
- The content of *Petunjuk* |

| 6. | KI/KD (Core competences and Basic Competencies) | ![Diagram](image4) | - Home button  
- *Petunjuk button*  
- Sound button  
- The text/menu: *KI/KD*  
- The content of *KI/KD* |

| 7. | Informasi (Information) | ![Diagram](image5) | - Home button  
- *Petunjuk button*  
- Sound button  
- The text/menu: *INFORMASI* |
| No  | Page | Design | Description |
|-----|------|--------|-------------|
| 8.  | Feedback for correct answers | Jawaban Benar | - The feedback appears when the answer is correct  
- In the feedback, there is a happy emoticon and the letter *Jawaban Benar*  
- After the feedback appears, the next question will appear. |
| 9.  | Feedback for incorrect answers | Jawaban Salah | - The feedback appears when the answer is incorrect  
- In the feedback, there is a sad emoticon and the letter *Jawaban Salah*  
- After the feedback appears, the next question will appear. |
| 10. | Video Petunjuk (instruction video) | | - Home button  
- *Petunjuk* button  
- Sound button  
- The text/menu: *PETUNJUK PERMAINAN*  
- Video *petunjuk permainan* (the game instruction video)  
- Next button: go to the game  
- Game logo |
| 11. | Score | | - Home button  
- *Petunjuk* button  
- Sound button  
- The text/menu: *LEVEL*  
- Information about total scores per level and criteria based on the level obtained  
- *Lanjut* (next) button: go to the next level |
| 12. | Game Over | | - This page appears when the user fails in the game (Game Over)  
- Game Over and Emoticons |
3.2. Discussion

The analysis of aspects proposed in the game design was carried out based on results of the needs analysis, so that this game can be appropriately and properly solve the existing problems. The overall aspects that exist in this game are the characteristics of the IG and EG, and the aspects of knowledge, skill, attitude, and motivation.

The characteristics of the IG consist of goals, rules, competition, challenges, fantasy, safety, and fun [7]. The IG aspects were chosen because this game model is precisely appropriate with the EG’s purpose to provide learning experience providing learning facilities that increase students’ abilities through EGs.

The aspect of knowledge emphasizes on what knowledge students must master. This aspect is derived from the KI/KD of the 2013 Curriculum of the Basic Programming. The selection of this aspect is in accordance with the objectives of the 2013 Curriculum that includes aspects of knowledge, skill, and attitude. Besides, based on the observation and needs analysis, the students’ knowledge of Basic Programming materials was still low, this is indicated by the students’ scores that were under the minimum criteria of mastery (79%), and that 81% of students had difficulties in Basic Programming. Factors that cause these difficulties for students are the unfamiliarity with the basic programming material (19%), difficulty in understanding programming algorithms (23%), difficulty to imagine the logic or process for developing programs (35%), lack of practice (7%), and unclear delivery of the material (16%).

Meanwhile, the skill aspect emphasizes on what skills students must acquire. It is derived from the KI/KD of the 2013 Curriculum of the Basic Programming. The selection of this aspect is in accordance with the objectives of the 2013 Curriculum that includes aspects of knowledge, skill and attitude. Besides, based on the observation and analysis, the students’ skills on the Basic Programming were still low. It was revealed that 44% of students could not develop the computer programming logic in the form of flowcharts, pseudocode, or natural languages, and that 37% of them were unable to perform so. Moreover, 47% of students were unable to use Programming Algorithm to solve problems and 33% of whom told they were less capable of doing so. As many as 49% were unable to use Branching Algorithm to solve problems and 35% said that they were less capable to do so. As many as 53% of students were unable to apply Loop Algorithm to solve problems and 30% stated that they were less capable in doing so.

Moreover, the attitude aspect emphasizes on increasing the students' curiosity, enthusiasm, and active participation during the learning process. This aspect is considered as important based on the results of the observation and questionnaire analysis on the students’ needs. This aspect was also chosen in accordance with the objectives of the 2013 Curriculum which includes the aspects of knowledge, skill, and attitude. Based on observations, the students’ enthusiasm in learning was still low, identified from the students’ reluctance during learning, that they were silent when not understanding the materials being taught. Additionally, the students’ curiosity towards the learning materials was also low.

The next aspect, motivation using the ARCS motivation design by Keller was chosen in this study. According to him, there are four important components of motivation, namely attention, relevance, confidence, and satisfaction [8]. Besides, based on the research conducted by James D. Klein and Eric Freitag, the use of IGs significantly affects these four components of motivation [9]. The motivation aspect in the EG is very important. Motivation is an internal state (within oneself) that awakens one to act, pushes them in a certain direction and makes them involved in certain activities [10]. Furthermore, learning motivation is a key element in learning that influences students' attitudes and learning outcomes [11]. Based on the results of a study conducted by Jeng-Chung Woo when designing DGBL, designers must increase the cognitive motivation and load to improve learning effectiveness [12]. This is in line with Park who states that games are one of the very possible ways to stimulate learners’ motivation [13].
Concerning this, the choice of the motivation aspects in this study is due to the students’ low motivation, indicated by 84% of students stating that they were less motivated when they attended the lessons and 79% of them felt bored while joining the Basic Programming classes. Students got bored during the learning process as it lacked of variation (35%), the delivery of material was less interesting (21%), the duration of the lesson was too long (12%), and 33% of students did not like the lesson because the materials were too complex to understand (33%). The characteristics of the EG in this study were adopted from those of the EG developed by Ibrahim and Jaafar. According to them, an EG should include three main components, namely game design, pedagogy, and learning content modeling [14].

The next development stage for the EG that will be carried out after the design stage is the stage of material collecting. At this stage, the materials needed in the game such as pictures and audios are collected. The later stage is the assembly stage, which includes combining the materials that have been collected in the previous stage. The following stage that is carried out after the assembly is testing, where alpha testing is carried out by the material experts and media experts. After passing the alpha test, beta testing will also be carried out by the Grade X VHS students. Lastly, the distribution stage where the educational game is disseminated to teachers and students will be carried out.

4. Conclusion

The integration of the learning model in the development of learning media is very imperative to improve the learning process. Therefore, this study develops an EG that is integrated with the IG learning model. In this paper, the developer formulated the design of the Basic Programming educational game using the IG in order to improve the students’ knowledge, motivation, and skills in the Basic Programming. Other aspects that exist in the EG model that are designed include the aspects of knowledge, motivation, skills, attitudes, and the characteristics of EGs. The selection of these aspects was based on the objectives of the 2013 Curriculum that includes the competencies on knowledge, attitude, and skills. In addition, the selection of these aspects was based on needs analysis, so that it is expected that the EG model designed can appropriately and accordingly solve the problems.

Acknowledgments

We would like to thank the reviewer for the comments and suggestions given. We also want to thank the school members, the teachers and students who participated in this study.

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