Field-independence versus field-dependence: a serious game on trigonometry learning

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Abstract. Mathematics is a subject that becomes a specter for students. Motivation is needed so that learning objectives are achieved. An effort to increase motivation is by using the serious game in learning. A serious game is another term for digital game-based educational games. Besides motivation, an important characteristic that students have is cognitive style. In this paper, the authors compare the field-independence and field-dependence cognitive styles on using a serious game on trigonometry learning. This study uses a qualitative descriptive research method. The research subjects were obtained from the Group Embedded Figure Test (GEFT) and were obtained 5 students who had field-independence (FI) cognitive style and 5 students who had field-dependence (FD) cognitive style. After students with FI and FD cognitive style were given a treatment by trying a serious game, the results obtained show that FI students got a higher score than that of FD students, they were able to solve problems on each floor in a short time and got fewer errors than FD students. Besides, FI students are more motivated to use a serious game than FD students.

1. Introduction
Mathematics is a subject that exists almost in every level of school. This shows that mathematics is an important subject. However, the reality shows that most students assume that mathematics is a difficult subject. This is indicated by the data from the National Examination [1] obtained from the Ministry of Education and Culture in Indonesia in 2017 that the average mathematics score is still very low, recorded scores at the level of state senior high school (SMA) are 41.39 for Science and 38.09 for Social Sciences majors. While the mathematics score at vocational high school (SMK) level is 36.81, it is lower than the high school level. There are many factors that can influence students’ learning. One of the factors is motivation. This is because of the higher students’ motivation in learning mathematics, the higher the possibility of learning. Based on the PISA results [2] from 70 countries only 27 countries that have motivation above the average and Indonesia are not included.

Motivation is an encouragement for students in learning. Motivation is also an inner factor that functions to generate, underlie, and direct in learning. Motivation can be a determinant of achieving learning goals so that the greater the motivation, the greater the success of learning [3]. One of the factors that can influence students’ motivation in learning mathematics is the use of learning media.

The use of interesting learning media will increase their motivation to learn. An interesting, interactive and fun learning media is a computer. By the reason, computers can stimulate students to be more interactive with the help of animated graphics, colors and music [4]. One type of learning media that uses computers is a serious game or often also called an educational game. A serious game [5] is a game concept which has a goal not only in giving fun and entertainment, but also providing knowledge experience to achieve learning goals through a guided environment.
Learning using a serious game will involve students to be active in learning and stimulate them to think. Varied and challenging game activities with pleasant situations make them enjoy the learning. A serious game can be made intentionally with a specific intention in order to increase certain abilities desired. A research survey conducted by Randel [6] illustrated that educational games are very beneficial for students because they can overcome different learning styles, provide direct feedback, increase learning motivation, and improve learning experiences and positive learning outcomes.

Besides motivation, a cognitive style also has an important role in achieving learning goals. Cognitive style has a significant influence on the choice of learning strategies [7]. Cognitive style is related to how students learn, both in receiving and processing all information. Cognitive style refers to the consistency and the tendency of individual characters to feel, remember, organize, process, think and solve the problems [8]. Cognitive style in this study is classified into a cognitive style of field-independence (independent views) and field-dependence (dependent views).

Cognitive style of field-independence is the cognitive style possessed by students who tend to express problems analytically, it means that a problem is broken down into small parts and finds a relationship between those parts. While the cognitive style of field-dependence is the cognitive style possessed by students so that they tend to state a problem as a whole and have stable characteristics [9]. In other words, a problem is seen as a whole unit, even though the unity can be broken down into small parts that are separated. By grouping, the cognitive style does not mean that one cognitive style is better than the other cognitive styles. Every cognitive style has its advantages and disadvantages.

Then what the connection between cognitive style and game-based learning (serious game) is. There is a connection between a serious game and cognitive style in terms of visual or spatial attention, memory load, verbal representation, etc. [10]. In the context of (serious) games, cognitive skills are needed by the players in solving problems, overcoming challenges, and interacting with the environment in the game so that they can complete the games [11, 12]. McDaniel and Kenny [13] investigated the impact of FD and FI cognitive styles on preconceived impressions and game enjoyment during learning activities, and found that there were differences in the difficulty of playing between FD and FI, FD shows general reluctance towards the use of games for learning activities. Similar results come from Naudet et al. [14] who studied the influence of a player's cognitive style on social network games that play in cultural heritage environments. However, the study only focused on the participant's playing experience, and not on the performance of the game. In short, research is needed to look at the performance of games from FI and FD in game-based learning from various aspects such as scores, time of completion, decision-making errors, and problem-solving processes. Thus, it is very interesting and necessary to examine the differences of FI and FD cognitive styles in mathematics learning using the serious game.

2. Method
This research belongs to the qualitative research. The research subject was determined by a cognitive style test that had been designed by Witkin [15], and it had been tested for its validity and reliability,
namely the Group Embedded Figure Test (GEFT). The procedure of research conducted in this study is divided into 4 stages as follows.

2.1. Preparation phase
The activities carried out at the preparation stage are: a) compiling research instruments, namely serious game made by the researcher and tested by several experts with the title "Trigonometria" and motivational questionnaires; b) performing validation of the instruments (validity, reliability, and distractors) [16] to the validators (experts); and c) analyzing the results of instrument validation then revise the instrument.

2.2. Implementation phase
Activities carried out at this stage include: a) selecting research subjects based on GEFT test results. From 30 students who were given GEFT instruments, it was obtained 5 subjects with field-independence cognitive style and 5 field-dependence cognitive style; b) giving a serious game "Trigonometria" for each subject to be solved its challenge; c) providing a motivation questionnaire to find out the effectiveness of serious game in learning.

2.3. Analysis Phase
Activities carried out at this stage are: a) reducing data with the aim to sharpen the information obtained; b) classifying and disposing unnecessary information and organizing raw data obtained in the field, processing and analyzing data obtained from each stage of implementation, namely game record completed by the subject and the results of the motivation questionnaire; then c) describing the results of data analysis.

2.4. Manufacture Report phase
Because this research is qualitative research, the main instrument is the researcher. The researcher is the determinant in data screening. At the time of data collection in the field, researchers participated during the research process and actively participated in the activities of the research subjects related to the data collection process. Supporting test instruments in this study are: Group Embedded Figure Test (GEFT). The material in this test is geometry. Students are given a few simple geometric shapes and then from a complex geometry of the test questions, they are asked to find a simple form that is in a complex geometry and build it up according to the question instruction. The test consists of 3 parts, the first part consists of 7 questions, the second part consists of 9 questions, and the third part also consists of 9 questions. The interpretation of GEFT scores according to Jeff Q. Bostic [17] in this study can be seen in Table 1.

| Category   | Male Students’ Score | Female Students’ Score |
|------------|----------------------|------------------------|
| Strongly FD| 0 – 9                | 0 – 8                  |
| Slightly FD| 10 – 12              | 9 – 11                 |
| Slightly FI| 13 – 15              | 12 – 14                |
| Strongly FI| 16 – 18              | 15 – 18                |

A serious game entitled "Trigonometria" is a game made by the researcher and has undergone various feasibility and validations tests based on previous research entitled "Guided inquiry-based game serious: An alternative media evaluation aid in mathematics learning". This game is used as a supporting instrument because it will be used to determine the score and see the time needed by students to solve problems in the game. As the name implies, this game contains problems related to
the trigonometry material. Students must solve the problems that exist on each floor. There are 6 floors, where 5 floors state each basic competence in trigonometry and the last floor is the ending game. Each floor consists of 5 questions, each of which has a low level of difficulty (1 question), moderate (3 questions), and high (1 question).

![Figure 2: Serious game “Trigonometria” (In game)](image)

This Serious game will measure the score of the game by completing the challenges of each floor, time in completing challenges, and many mistakes made by the player which is indicated by the number of remaining life points.

**Motivation Questionnaire.** This questionnaire is a question consisting of 20 items. Indicators contained in the motivation questionnaire are: 1) the existence of encouragement and learning needs; 2) the existence of hopes and aspirations for the future; 3) being persistent in facing difficulties; 4) showing interest in various problems; 5) tending to work alone; 6) getting bored quickly on routine tasks; 7) able to maintain his opinion; 8) enjoying looking for and solving questions; 9) being happy to take the lessons; 10) being diligent in learning and facing mathematics tasks.

Data collection used in this study was the test method. In the test method, subjects were given the serious game "Trigonometria" in which there were related questions about the trigonometry material and had different levels of difficulty (low, moderate, and high). Data record results from the serious game "Trigonometry" are in the form of the duration or time needed to complete each floor and the score obtained in each floor. Meanwhile, for the motivation questionnaire test given is to determine the effectiveness of the media "Trigonometria", whether it is able to make students more motivated in solving problems in the game rather than a written test. In this study, data analysis was carried out with the following steps.

### 2.5. Analyzing GEFT results

The GEFT test results are used to determine the research subjects. Determination of students in the field-independence and filed dependent cognitive style group is based on the speed and accuracy of students in finding simple images in more complex images with the time limit specified in the GEFT instrument. The number of questions in the GEFT test is 25 numbers. Assessment is done by giving score 1 for the correct answer and 0 for the wrong answer. Thus, if students are able to answer the questions correctly then the maximum score is 25 and the minimum score is 0. For the categorization of cognitive style are used criteria: 1) If the score obtained is more than 50%, it includes the field-independence cognitive style group; and 2) If the score obtained is less than 50%, it includes the field-dependence cognitive style group.
2.6. Analyzing the data results of the "Trigonometria" serious game
Analyzing the records results of the "Trigonometria" serious game aims to determine the duration or time needed to complete the game and find out the total score obtained at the end of the game based on its cognitive style.

2.7. Analyzing the results of the motivation questionnaire test
The analysis results of the motivational questionnaire test were conducted with the aim to know the effectiveness of the "Trigonometria" serious game whether it is able to make students more motivated in solving problems in the game rather than presented written test.

2.8. Reducing the data
The collected data is then reduced. Data reduction in this research is an activity that refers to the process of selecting, classifying, or simplifying raw data obtained in the field.

2.9. Describing the data
Describing data is a group of organized information that makes it possible to draw a conclusion. The data in this study are to clarify and identify data regarding the differences of field-dependence and field-independence cognitive styles in mathematics learning using the serious game.

2.10. Drawing a conclusion
The conclusion drawn in this study is to describe the differences of field-independence and field-dependence cognitive style in mathematics learning with the serious game.

3. Result
This research belongs to the qualitative research category. The research subject was determined by using the GEFT instrument. From 30 students who were given GEFT instruments, it was obtained 20 students with independent field cognitive style and 10 students with field-dependence cognitive styles. In addition, the subject must also bring a laptop for more than 2 weeks. There were 12 students who were not selected as the subjects because they did not have laptop and 8 students who were not selected as the subjects because they bring laptop less than 2 weeks, so that there were 10 students with FI subjects (n = 5) and FD (n = 5) who have the criteria needed.

Mathematics material used in the serious game is trigonometry. The research subjects had been given trigonometry material before being given a serious game instrument. There are 5 basic competencies tested in each floor, the first floor determines trigonometry comparisons on right triangles, the second floor determines angular values related to various quadrants, the third floor converts polar coordinates to Cartesian coordinates and vice versa, the fourth floor applies sine and cosine rule, and the fifth floor determines the area of a triangle with trigonometry concepts. At the end of the floor or on the top floor there is a final boss that must be defeated.

To defeat the boss, the subject must answer 5 questions with a high level of difficulty. Based on the results of the "Trigonometria" serious game data record, subjects with the FI cognitive style show that to complete the first floor game it takes 35 minutes on average. To complete the first floor of the subject FI, the average loss life point is 0 - 1. For the second floor, the average time is around 35 minutes. On the second floor, FI subjects lost 1 life point on average. For the third floor, the average time is longer, which is 40 minutes. On the third floor, FI subjects lost 2 life points. For the fourth floor, it takes a longer average time of 45 minutes. On the fourth floor, FI subjects lost 2 life points on average. For the fifth floor, it takes around 50 minutes on average. On the fifth floor, FI subjects lost 2 life points on average. On the last floor or the top floor, subject FI requires an average time around 60 minutes and must lose 4 life points. The average answer from subjects with the FI cognitive style tends to be short and less structured. Figure 4 shows the score obtained by the five FI players for each floor.
The score of FI players.

Figure 3: The score of FI players.

Whereas for subjects with FD cognitive style to complete the first floor it takes an average time about 50 minutes. On the second floor, the subject of FD did not lose at all the life point. For the second floor, FD subjects solve it with an average time about 55 minutes. On the second floor, FD subjects lost about 1 life point. For the third floor, the FD subjects completed it with an average time of around 60 minutes. On the third floor, FD subjects lost about 1 life point. For the fourth floor, FD subjects completed it with an average time of around 65 minutes. On the fourth floor, FD subjects lost about 2 pieces of life points. For the fifth floor, the FD subjects solve it with an average time around 50 minutes. On the second floor, FD subjects lost 1 life point. On the last floor or at the top, FD subjects require an average time around 90 minutes and have to lose 2 life points. Average answers from subjects with FD cognitive style are longer and structured. Figure 5 shows the score obtained by the five FI players for each floor.

Based on the results of the motivation questionnaire test given by each subject with field-independence and field-dependence cognitive style, the results showed that the subjects were more interested in solving the problem in the game rather than having to solve the questions the teacher usually gave in the form of written test. Students are more motivated to solve the problems in the game because they feel challenged. However, as stated by McDaniel and Kenny [13], students with a field-dependence cognitive style, they were less interested in using a serious game in learning compared to field-independence cognitive style students who showed enthusiasm in using the game.

4. Conclusions
Based on the results of analysis of research data conclusions are obtained as Subjects with field-independence cognitive style in completing the game on each floor get an average score obtained relatively high and require time or a relatively short and fast duration. Almost on every floor, field-independence cognitive style subjects spend a little life point to solve the problem. If viewed from the answer of field-independence cognitive style subjects, it is more structured and has an appropriate answer in accordance with the analysis and logic. The steps used are not sequential and the concepts used are based on subject logic. Scores obtained at the end of the game are higher than subjects with field-dependence cognitive styles.

In completing the game on each floor, subjects with field-dependence cognitive style get an average score obtained lower and require a relatively long time or duration. Almost every floor, field-dependence cognitive style subjects spend more life points to solve the problem. When it is viewed from the answers, field dependent cognitive style subjects’ answer is very short and has answers based on the examples.
given by the teacher. The steps and concepts used in solving the problem are in accordance with those exemplified by the teacher. The scores obtained at the end of the game are lower than that of field-independence cognitive style subjects.

Both field-independence and field-dependence cognitive styles subjects are more interested and motivated to solve problems that are packaged in a game rather than having to solve questions or problems that are given directly in the form of written or paper test. They are more interested in solving problems (questions) in the game because they feel challenged by the game. However, there are other findings that when it is compared with students with field-independence cognitive style, while students with field-dependence cognitive style have less motivation to use a serious game.

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