Gamified experimental data on physics experiment to measuring the acceleration due to gravity

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Abstract. This research is a first step in the model design of gamification in physics experiment that engage pre-service physics teachers (PPTs) to an experiment system designed like gameplay. The implementation of gamification in physics experiment to measuring acceleration due to gravity (g) using the application of physical phone experiments (phyphox) on smartphone. It was involved 25 PPTs at one of the University in Bandung. This quasi-experimental research used one-group-pretest-posttest design. Data were collected through tests. The result of data analysis shows that there were significant differences in the PPTs' concept mastery before and after following the physics experiment with implementing gamification. The increasing of PPTs' concept mastery can be categorized as medium (\( \frac{\Delta g}{g} = 0.30 \) and \( d = 0.32 \)). The model of gamification in physics experiment that was designed create the atmosphere of physics experiment more fun and competitive, promoting motivation to engage in physics experiment activities such as observing, collecting data, analyzing data, inferring and communicating. Further development, this model of gamification needs to be supported by a system that can integrate the assessment automatically. It will be facilitate lecturers in conducting product and process assessments.

1. Introduction
Physics is one of science considered difficult to be studied by pre-service physics teachers (PPTs). Basic Physics is one of the courses that must be enrolled by PPTs in research population. One of the topics in the Basic Physics course that the competence is still low is the topic of motion in one dimension. In terms of the content, this topic involves the physics quantity to describe the motion of an object such as position, displacement, speed and acceleration. This topic is closely related to the phenomena found in everyday life [1]. To understand the physics phenomena on the topic of motion in
one dimension, it requires an experimental design that can facilitate PPTs learning on constructing and discovering the physics concepts whether done individually or in groups. One of the most interesting on physics experimental objectives is the experiment designed to measuring the acceleration due to gravity \( (g) \).

### 1.1. Study of Physics Experiment to Measure the Acceleration Due to Gravity \((g)\)

The result of the study related to the method of physics experiment shows that there are various methods that can be used to measure the value of \(g\). The research was developed a method to measure the value of \(g\) using a computer microphone port [2], applying the concept of simple harmonic motion by using the pendulum method [3], applying the principle of physical pendulum and projectile motion [4], designed a pendulum motion system apparatus consisting of mechanical and electronic systems [5], applying the concept of projectile motion and using tracker video analysis software [6] and using microcomputer based laboratory (MBL) and Logger Pro software [7].

Along with the development of science and technology, the use of smartphone has been widely used to support the effectiveness of physics experiment. One of the smartphone applications that can be used in physics experiment is \textit{Physical Phone Experiments} (PhyPhox). This application developed by RWTH Aachen University (http://phyphox.org). One of the physics experiments that have been practiced using phyphox application is free fall motion experiment (FFME) which is intended to measuring the value of \(g\) [8]. FFME was designed to measuring the value of \(g\). FFME design that used in this research refers to the design developed by Staacks [8] at RWTH Aachen University. This experimental design was chosen because generally PPTs at the research site using smartphone. In addition, the duration of a free fall recorded by acoustic stopwatch sensors in phyphox can be exported into a file format that are supported on excel which can be shared via Bluetooth, email, BBM, Share it, wifi and also WhatsApp [9]. In this research, it aims to communicate the results of physics experiments using WhatsApp. In addition, this media are also used for monitoring physics experiment activity.

### 1.2. Game and Gamification in Education

The game is defined as a system in which players engage in an abstract challenge, defined by rules, interactivity, and feedback that result in a quantifiable outcome, often eliciting an emotional reaction [10]. Various studies have shown the successful of using games in learning physics concepts such as: the global warming concept [11], Newton's laws [12], the concept of force [13], electric energy consumption and conservation [14], optics [15-16] and electromagnetic [17]. Generally, the use of games in physics learning is mostly done at the elementary and secondary level [1]. In the context of higher education, the use of game elements has the potential to increase the effectiveness of lectures.

Gamification is defined as the use of game design elements in non-game context [18-20]. In other literature, gamification can be defined as using game-based mechanics, aesthetics, and game thinking to engage people, motivate action, promote learning, and solve problems [10]. In the context of higher education, gamification is very potential to be applied in lectures, especially in physics experiment. The previous studies show that the implementation of gamification could promote the student’s motivation [21] and engagement in lecture activities [22-28]. In this article, FFME will be designed like a gameplay, collaboratively worked to measuring the value of \(g\). The implementation of gamification is expected to motivate PPTs to be more engage in the series of physics experiment activities.

### 2. Methods

#### 2.1. Design, Participants, and Research Instruments

The study was conducted on 25 PPTs (M = 6, F = 19, average age 18 years old) at one of the University in Bandung. This study is a quasi-experimental research with one-group-pretest-posttest design. The data were collected through tests. The data of PPTs’ concept mastery were analyzed descriptively.
2.2. Free-Fall Motion Experiment (FFME) Procedure

Free fall motion (FFM) is the motion of the fall of an object without the initial velocity. If the air resistance (drag force) is ignored, the force acting on the object is only the force of gravity. The object will experience free falling motion with downward acceleration equal to the acceleration due to gravity.

In the FFME, a load of object is attached to a balloon placed on a circular wire that has been attached to the stands with a certain height \( y \). The duration of a free fall can be determined by using the acoustic stopwatch on phsyphox application. The explosive sound of the balloon becomes an indicator of initial time and the sound of falling objects on the floor becomes an indicator of the final time. The difference between the final and initial time is the duration of a free fall. Before the application of acoustic stopwatch sensor is run, it is necessary to adjust the value of threshold and minimum delay so that the environmental noise parameters do not interfere with the measurement of the duration of a free fall. Since the initial velocity of the object is zero, the value of \( g \) can be calculated by substituting the duration of a free fall \( t \) and height \( y \) in the FFM equation. The value of \( g \) can also be calculated by analyzing the graphical relationship between time and height (Staacks, 2017). Modified design of media on FFME can be shown on figure 1.

![Figure 1. Design of Media on FFME](image)

3. Results and Discussion

3.1. Gamification in Physics Experiment Context

The implementation of gamification in the physics experiment context is aimed for engaging PPTs in an physics experimental system designed like a gameplay that can create a joyful and competitive practical atmosphere, promoting PPTs motivate to be more engage in a range of physics experiment activities such as observing, collecting data, analyzing data, communicating the results of the experiment. In this research, the monitoring of physics experiment activities and communication the result of experiment was done by using WhatsApp. Monitoring the physics experiment activity are still limited, such as uploading the data of experiment, downloading the data of experiment, uploading the results of data analysis and uploading the photo or video of the physics experiment activities. Assessment by lecturers is still done manually, then the results of the assessment and determination of the best group (leaderboards) uploaded through WhatsApp.

The game elements used in the physics experiment context to measure the value of \( g \) are described as follows; 1) Challenge; the challenge given is the task to measuring the value of \( g \), 2) Skills; skills required in this gamification are the science process skills that include observation, interpretation, communicating, planning the experiments and applying concepts or principles, 3) Rules; the rule used is the concept of free fall motion, 4) Point; points that PPTs can obtain from the assessment of the worksheet, upload and download of physics experiment data through WhatsApp, data processing and
conclusions, 5) **Badge**: certificates are given if the PPTs are able to produce experimental data, upload and download the experiment data, able to analyze data and communicate the results of experiment, 6) **Leaderboards**: the achievement position of each group is based on the assessment made by the lecturer. The leaderboards is uploaded through WhatsApp. An overview, the implementation of gamification in physics experiment context is shown in Figures 2.

![Gamification in Physics Experiment Context](image)

**Figure 2.** The Overview of Gamification in Physics Experiment Context

### 3.2. The Impact of The Implementation of Gamification in Physics Experiment toward PPTs’ Concept Mastery

The results of the paired-samples t-test showed that there were significant differences in the PPTs’ concept mastery before and after following the FFME with implementing gamification. The average skor of pretest, posttest and statistical test results can be shown in Table 1.

The increase of PPTs’ concept mastery for each cognitive ability test can be shown in Figure 3. Based on Table 1 and Figure 3, generally there is an increase in the concept mastery of PPTs in the concept of FFM. The increase of concept mastery was categorized as medium that shown by the normalized gain ($g = 0.30$) and the effect size ($d = 0.32$).

| Tests   | $X_{ideal}$ | $\bar{x}$ | $s$   | $(g)$ | Effect Size ($d$) | One-Sample Kolmogorov-Smirnov Test (Sig.) | Levene Test (Sig.) | Paired-Samples $t$ Test |
|---------|-------------|-----------|-------|-------|-------------------|------------------------------------------|-------------------|--------------------------|
| Pretest | 8.00        | 5.04      | 1.81  | 0.30  | 0.288             | 0.633                                    | $t = -6.063$; Sig. 0.000 |
| Posttest| 8.00        | 5.92      | 1.61  | 0.32  | 0.571             |                                          |                   |                          |

For the first question, PPTs are required to determine the order of the fall of three objects with different mass, which are dropped simultaneously from a certain height if they are in a vacuum. Percentage of PPTs’ concept mastery has increased from 80% (high) to 88% (very high). This increase can be categorized as medium (0.40). For the second question, PPTs are asked to predict the acceleration of an object that free fall from a certain height. Percentage of PPTs’ concept mastery has increased from 28% (low) to 52% (medium). This increase can be categorized as medium (0.33). On the third question, PPTs are required to determine the order of the speed of three objects with different mass dropped simultaneously from a certain height just before hitting the ground.
Percentage of PPTs’ concept mastery has increased from 76% (high) to 88% (very high). This increase can be categorized as medium (0.50). For the fourth question, PPTs are asked to predict the speed of an object that has free fall from a certain height. Percentage of PPTs’ concept mastery has increased from 68% (high) to 72% (high). The increase of the concept mastery on this item is categorized as low (0.13).

The fifth question, PPTs are asked to name examples of FFM. Percentage of PPTs’ concept mastery has increased from 92% (very high) to 96% (very high). This increase of the concept mastery on this item is categorized as medium (0.50). For the sixth question, PPTs are asked to classify the type of FFM into the motion with constant acceleration. The level of concept mastery did not increase after learning on this item. Level of the PPTs’ concept mastery on this item is 72% (high).

For the seventh question, PPTs are asked to name the characteristics of FFM. Percentage of PPTs’ concept mastery has increased from 56% (medium) to 64% (high). The increase of the PPTs’ concept mastery on this item is categorized as low (0.18). On the eighth question, PPTs are asked to explain how to determine the duration of a free fall. Percentage of PPTs’ concept mastery has increased from 32% (low) to 60% (medium). The increase in the concept mastery on this item is categorized as medium (0.41).

3.3. Critical Analysis to The Implementation of Gamification in Physics Experiment
In the research population, there is a unique phenomenon that occurs inaccurate of the calculated value of \( g \) obtained in each group as shown in photo samples on figure 4. The experiment data considered to be inaccurate in group I (the 2nd and 3rd experimental data), group II (the 1st experimental data), in group III (the 1st, 2nd and 3rd experimental data) and group IV (the 1st and 2nd experimental data). The inaccurate data of this experimental result were found by PPTs when they are discussing in their respective groups after downloading the experimental data from the other group.

Based on the experiments that have been done, the measured variable consists of the height of free falling objects \( y \) and the duration of free fall \( t \). Several factors are potentially a source of error among others; 1) parallax error when reading the height of the object that was free fall and 2) the error when measuring the duration of free fall by using phyphox smartphone application. The results of the analysis and reflection show that the duration of free fall by using phyphox smartphone application becomes the main source of the error of physics experiment data. Each group automatically records the duration of free fall using an acoustic stopwatch sensor in phyphox application. The explosive sound of the balloon becomes an indicator of initial time and the sound of falling objects on the floor becomes an indicator of the final time. The difference between the final and initial time is the duration of a free fall. Each group sets the same value of the threshold and minimum delay that is 0.5 a.u. and 0.1 seconds.
The source of the error is not on the phyphox application, but rather due to the improper implementation settings of the physics experiment while doing research. During the experiment, 25 PPTs were grouped into four groups. Each group is 3 meters apart with each other. In the same time and space, the experiment on the measuring the value of \( g \) is done simultaneously in the four groups. Each group has the same indicator of time, the explosive sound of the balloon and the sound of falling objects on the floor. Because the experiment is done in the same time and space, the explosive sound of the balloon and the fall of objects to the floor coming from one group is strongly suspected still can be detected by smartphones in the other groups, so this is what is allegedly as one of the sources of error.

![Figure 4. Photo sample of the PPTs’ Experimental Data Processing](image)

On the other hand, there is no standard for balloon size causing the different of balloons size that have been blown by each group. In fact, the larger the balloon size, the stronger the sound of the balloon explode that can disrupt the measurement of the duration of a free fall through the smartphone in other groups. In addition, based on figure 5, the inter-group spacing (d = 3 meters) still allows the smartphone used still to be able to detect the explosive sound of the balloon from the other groups. During the experiment, PPTs may not realize that the sounds detected by smartphones in their group are the sounds that come from other groups causing the measurement of duration of a free fall to be inaccurate, which can ultimately affect the result of determining the value of \( g \).

![Figure 5. Room Settings during the Implementation of Gamification in FFME](image)

An interesting finding of the implementation of gamification on this physics experiment is the sharing of experimental data, so that each group will get more experimental data with the same amount obtained from each group. Data from other groups becomes the group data that must be analyzed and evaluated. With this activity, the mistakes was made during experiment by a group can be detected early on by the PPTs and it’s can be a more interesting discussion material so that the atmosphere of physics experiment becomes more joyful and competitive. Through discussion and reflection, PPTs can correct their mistakes and jointly lead to the reconstruction of right concepts.

4. Conclusion
Based on the results of data analysis, it can be concluded that the implementation of gamification in the physics experiment context can engage PPTs to an experiment system designed like a gameplay so that the experiment atmosphere can be created more fun, competitive, and promoting PPTs motivation to be more engaged in a series of experimental activities such as observation, collecting.
data, analyzing data, inferring and communicating experimental results. The implementation of gamification in physics experiment to measuring the value of g using the Phyphox smartphone application can improve PPTs’ concept mastery related to FFM concept. The increasing of PPTs’ concept mastery was categorized as medium ($g = 0.30, d = 0.32$).

For further research, it is necessary to design a physics experiment gamification system that can integrate the assessment automatically, so that PPTs can see the sequence of achievement through the leaderboard. In addition, in the gamification system, it is necessary to integrate the PPTs’ portfolio so that it can automatically record the physics experiment activities that were conducted by PPTs. The gamification system that integrated with automatic assessment is expected to improve the effectiveness of the physics practices as well as facilitate lecturers in carrying out the assessment of product and process.

**Acknowledgment**
The authors would thank to LPDP BUDI-DN who has funded this research and as the main sponsor through the scholarship of doctoral education program.

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