How Games are Designed to Increase Students’ Motivation in Learning Physics? A Literature Review

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Abstract. Game is a promising tool to help students in understanding physics concept. It can motivate and provide the opportunities for students to become independent in learning. In order to fulfil these functions, games should be carefully designed. Thus, the objective of this paper is to present how games are designed to increase students’ motivation in learning physics based on several literature reviews. The results showed that there are several ways to increase students’ motivation in learning physics and to achieve that, game dimensions are needed to be considered when designing a game. This literature review may have useful to assist teachers and contribute in improving the design of games.

1. Introduction
The impact of games on life has increased significantly over the last few years. The increasing number of gamers in Indonesia is much higher compared to other countries. According to survey result conducted by Unity (Figure 1), the number of games installed in Indonesia during the year 2015-2016 has increased 192% from previous year [1]. This increase is several times more than in other countries. The number of gamers in Indonesia are about 21 million [2] and they play games on average three times a day [3]. According to these data, it can be concluded that games have been filled most of our leisure time now.

Playing games can give many positive effects. One of the positive impacts of playing games is it can enhance cognitive functions that include: problem solving, spatial skills, and creativity [4]. Another positive effect that can be obtained when playing games is it can satisfy basic psychological needs, such as: competence, autonomy, relatedness, and mastery off controls [5]. Furthermore, a more recent study indicates that when games are integrated with mathematics, it can engage and motivate students [6].

Motivation provided by games can help students when learning physics. All this time, many students still regard physics as difficult, abstract, and boring subject. With the games integrated in learning physics, students are expected to learn while playing so they can enjoy their learning process. In addition, more play will improve learning and performance [7]. Adding fun in the learning process will make it becomes enjoyable, compelling, and effective [7]. Moreover, games can also help students to be independent in learning.
Although games can give positive effect in learning, games can also give negative effect. This depends on game design that is used in learning. Thus, this systematic literature review is conducted in order to find out how to design games that can increase motivation for students. Furthermore, it may also assist teachers and contribute in improving the design of games.

2. Background

2.1. Games for Education

Game is an organized play that is fun and engaging [7]. The word game is often associated with play and fun. Both of it can also make learning easier. Play can provide pleasure and increase involvement in learning [7] while fun can put students in relax and receptive mind for learning [8].

Many studies found that games can give positive impacts to student performances in school. These impacts depend on the types of games played by the students. There are 8 types of games that are action, adventure, fighting, puzzle, role playing, simulations, sports, and strategy [7].

Games have motivational power that makes learning fun and can be a powerful learning tool by engaging students to learning through doing [9]. However, game can also become a distraction for learning process. It depends on the game design and there are 6 design elements that need to be considered when designing a game. Those elements are: (a) rules, (b) goals and objectives, (c) outcomes and feedback, (d) conflict/competition/challenge/opposition, (e) interaction, (f) representation or story [7]. Besides that, there are 6 key dimensions of game, that is: (a) fantasy, (b) rules/goals, (c) sensory stimuli, (d) challenge, (e) mystery, (f) control [10]. All of these elements and dimensions are what affect students’ motivation in learning physics.

2.2. Motivation in Learning Physics

There are two kinds of motivation that are intrinsic and extrinsic motivation. Intrinsic motivation is the desire to perform the task for their own sake because they find it fun and challenging and extrinsic motivation is related to rewards [11, 12]. These two motivations can give different effect to students in learning process. Intrinsic motivation results in high quality learning and creativity but teacher cannot always rely on it because not all the tasks that needed to be performed by the students are enjoyable and interesting [12]. Extrinsic motivation has limited effect and reduces students’ motivation to do similar task in the future but it can also boost intrinsic motivation [11].
One way to motivate students in learning physics are making the activity interesting and make achieving the outcome becomes the important thing to do [10]. Recent study show that students are motivated to study physics when using modern information technology, computer, internet, and mobile phones [13].

3. Discussion
The effect given by games in learning is determined by its design. So, when designing a game, there are several things that are needed to be considered. One thing that needs to be considered is game dimensions, including: fantasy, rules/goals, sensory stimuli, challenge, mystery, and control. Fantasy in games allows students to do actions that have no effect in real world, but have real consequences [10]. Fantasy in games should depend on the practice of skills and vice versa (endogenous fantasy) [18]. Another way to add fantasy in games is by using meaningful stories [14, 20]. For examples, when students need to learn about vectors, they can do it by piloting a plane in a game. When they don’t take the game seriously, they will get real consequences because their plane will be crashed. Thus fantasy in piloting the plane is depended on students’ competence in vector and vice versa. This can give excitement to students and teach them to be responsible thus can improve their intrinsic motivation in learning. Besides that, the relevance of the situation while piloting the plane to the real life will motivate students in learning physics.

Rules/goals need to be clear, specific, challenging, and difficult goals but not impossible to do [10, 18, 19]. Giving difficult goals in games will enhance students’ performance [10] and to prevent students to give up in the middle of playing, the goals should be started by an easier one, and then improved step by step. By achieving goals one by one starting from easy to hard, students will get excited and become curious about what will happen after they are making progress in game. This condition will help them learn physics concept in the game gradually and give enjoyment while learning it. Besides that, students will be more motivate if the game highlights the consequences result of a goal and emphasizes the importance of students’ action within a given situation [20]. Furthermore, if the tasks in game are time-based, the number of tasks and time period to finish it should be calibrated carefully [19]. Rules use in game should encouraging reflection by embedding and rewarding reflection assignments [18], so students will learn from their mistake and elaborate their learning if they already understand the material when playing game.

Sensory stimuli in games including sound effects, dynamic graphics, and animation are needed in games to become students’ attention grabbing [10, 22]. One thing to be remembered when design the sound of the game is it should not distract students’ attention more than the game play itself. Other sensory stimuli that can be used are avatar, player skill level, and profile development [14, 19, 20]. These will give the sense of autonomy (ability to choose for oneself to engage in activity [24]) to students, thus increase their intrinsic motivation.

Challenge in game should be neither too easy nor too difficult, clearly specified, yet the possibility of obtaining the goal should be uncertain [10] and align the challenging level with students’ competency level [18]. Performance feedback and score keeping is needed in game [10] to help students be aware of their success rate in game play. Feedback in game can give significant increase in motivation [16]. Feedback use in game can be in the form of positive and negative reinforcement. Positive reinforcement can be given after students complete a difficult task and if it is in the form of reward, it can be used to help them complete next task. This way, their extrinsic motivation will increase because of their eagerness to get the reward so they can continue their game play easier. This condition will also make achieving the outcome becomes the important thing to do by students. Another form of feedback that can be used in game are points, badges, leader boards, level, progress bars, performance graphs, quests, and team play [14, 15, 18, 20, 21, 23]. By using ranking scores among peer students, can help increase their extrinsic motivation [12].

There are several things to remember when designing rewards in game. Reward is given based on the quality (proportion of the items solved versus the items tried) not on the quantity of performance (total of items solved correctly) [18]. This condition will make students do their best in playing games,
not just guessing or do trial and error until they find the right answer. Furthermore, reward should be given at the end of each playing cycle, so it will become part of the outcome processing [17] to help students evaluate their learning progress.

Mystery in game will generate students’ curiosity and curiosity is one of the primary factors that drive learning [10]. For example, adventure game can be used in learning fluid concept. The game can start with someone get stranded in a deserted island and try to get back home. In this game, student can help the person by using fluid concept. The situations encountered by the person will give the sense of mystery to the students and by helping the person, students will automatically solving lots of problem which is the way to understand physics. Another condition that can help in creating mystery in games are by using randomly selected input and varies difficulties for task, thus keeping the game interesting and engaging [19].

Control is the ability to regulate, direct, or command something [10]. Students need to be given the ability to control how to proceed with the game play. This will make them enjoy the game and will give them more excitement when they can achieve the game goals with their own way. Besides that, game user interaction interface should be carefully designed in order to hinder wild guess by students. One way to achieve this condition is to avoid multiple choice that enable random clicking [18]. Furthermore, if the game is time-based, time limit and time remaining is need to be displayed through the game [19], so students will know their remaining time to complete the games’ goal, thus can determine the best way for them to use the remaining time effectively to get maximal outcome. The summary of the relation between game dimensions design and motivation is concluded in Table 1.

**Table 1. Relation Between Game Dimensions Design and Motivation**

| Game Dimensions | Design | Motivation | References |
|-----------------|--------|------------|------------|
|                 |        | Intrinsic  | Extrinsic  |            |
| Fantasy         | Design endogenous fantasy | ✓ | | [18] |
|                 | Use meaningful stories | ✓ | | [14], [20] |
| Rules/Goals     | Set specific and challenging goal | ✓ | | [10], [18], [19] |
|                 | Rules that encouraging reflection by embedding and rewarding reflection assignments | ✓ | | [18] |
|                 | Calibrated number of task to complete and time period | ✓ | | [19] |
|                 | Clear, difficult, but achievable goal | ✓ | | [10], [20] |
|                 | Highlights the resulting consequences of a goal | | ✓ | [20] |
|                 | Emphasizes the importance of students’ action within a given situation | ✓ | | [20] |
| Sensory Stimuli | Use player skill levels | ✓ | | [19] |
|                 | Use avatars and profile development | ✓ | | [14], [20] |
|                 | Use sound effects, dynamic graphics, and animation | ✓ | | [10], [22] |
| Challenge       | Clearly specified, yet the possibility of obtaining the goal should be uncertain | ✓ | | [10] |
|                 | Use badges, leader boards, and performance graphs as performance feedback | ✓ | ✓ | [14], [15], [18], [20], [21], [23] |
|                 | Use ranking scores among peer students | | ✓ | [17] |
|                 | Game rewards received at the end of each playing cycle | ✓ | | [17] |
|                 | Align the challenging level with students’ competency level | ✓ | | [18] |
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| Game Dimensions | Design | Motivation | References |
|-----------------|--------|------------|------------|
|                 |        | Intrinsic  | Extrinsic  |            |
| Intrinsic       |        |            | √          | [10], [18] |
| Extrinsic       |        |            |            |            |

Reward is given based on the quality not on the quantity of performance
Feedback should be informative elaborated, not just summative feedback
Assign point for each successful output produced during the game and score summary for performance feedback
Feedback in form of positive and negative reinforcement
Use points, level, progress bars, quests, and team play

| Mystery         |        |            |            |            |
|                 |        |            | √          | [20], [21], [23] |
|                 |        |            |            | [20] |

Input are randomly selected
Use varies difficulty for task

| Control         |        |            |            | [18] |
|                 |        |            |            | [18] |

Game user interaction interface is designed to hinder wild guess
Display time limit and time remaining through the game

|                |        |            |            |            |
|                |        |            |            | [18] |

### 4. Conclusion

Games can increase students’ motivation in learning physics because it makes learning become fun and enjoyable. It can also increase their intrinsic and extrinsic motivation in learning physics. Another motivation needed by students in learning physics are relevance to the daily life, making the activity interesting and make achieving the outcome becomes the important thing to do. In order to increase motivation, game dimensions such as fantasy, rules/goals, sensory stimuli, challenge, mystery, and control are needed to be considered when designing a game.

### References

[1] SuperData and Unity 2017 *Can’t Stop, Won’t Stop: 2016 Mobile and VR Games Year in Review* (SuperData Research and Unity Technologies) p 8

[2] Mareza B 2016 *Ayo Cek, Kamu Termasuk Kecanduan Game Online?* https://student.cnnindonesia.com/edukasi/20160211134438-317-110344/ayo-cek-kamu-termasuk-kecanduan-game-online/

[3] Maulana R 2017 *Tingkat Perkembangan Pasar Game Mobile Indonesia Tiga Kali Lipat Amerika Serikat* https://id.techinasia.com/perkembangan-pasar-game-indonesia-salah-satunya-tingtinggi-di-2016

[4] Isabela G, Adam L and Rudger C 2014 *The Benefits of Playing Video Games* American Psychological Association Vol. 69 No. 1 p 69

[5] Andrew K P, Richard M R and C Scott R 2010 *A Motivational Model of Video Game Engagement* Review of General Psychology Vol. 4 No. 2 p 155-156

[6] Wijers M, Jonker V and Kerstens K 2008 *Proc. of the 2nd European Conf. on Games-Based Learning (ECGBL)* (Barcelona: Spain) p 513

[7] Prensky M 2001 *Digital Game-based Learning* (New York: McGraw-Hill)

[8] Mitchell A and Smith C 2004 *The Use of Computer and Video Games for Learning: A Review of The Literature* (United Kingdom: Learning and Skills Development Agency) p 2
[9] Kirriemuir J and Mcfarlane A 2004 Literature Review in Games and Learning. A NESTA Futurelab Research report - report 8. 2004, p 4
[10] Garris R, Ahlers R and Driskell J E 2002 Games, Motivation, and Learning: A Research and Practice Model *Simulation and Gaming* Vol. 33 p 447–451
[11] Benabou R and Tirole J 2003 Intrinsic and Extrinsic Motivation *Review of Economic Studies* Vol. 70 p 490, 492
[12] Ryan R M and Deci E L 2000 Intrinsic and Extrinsic Motivation: Classic Definitions and New Directions *Contemporary Educational Psychology* Vol. 25 p 55
[13] Holubova R 2015 How to Motivate Our Students to Study Physics? *Universal Journal of Education Research* 3(10) p 733
[14] Michael S, Jan U H, Sarah K M and Heinz M 2017 How Gamification Motivates: an Experimental Study of the Effects of Specific Game Design Elements on Psychological Need Satisfaction *Computers in Human Behavior* Vol. 69 p 378
[15] Carloz C, Michael D H and Jesse F 2015 The Need to Achieve: Players’ Perception and Uses of Extrinsic Meta-game Reward Systems for Video Game Consoles *Computers in Human Behavior* p 8
[16] S Erhel and E Jamet 2013 Digital Game-based Learning: Impact of Instructions and Feedback on Motivation and Learning Effectiveness *Computers & Education* Vol. 67 p 162
[17] Wen-Hao H, Wen-Yeh H and Jill T 2010 Sustaining Iterative Game Playing Processess in DGBL: the Relationship Between Motivational Processing and Outcome Processing *Computers & Education* Vol. 55 p 794-795
[18] Fengfeng K 2008 A Case Study of Computer Gaming for Math: Engaged Learning from Gameplay? *Computers & Education* Vol. 51 p 1614-1619
[19] Luis V A and Laura D 2008 Designing Games with a Purpose *Communications of the ACM* Vol.51 p 63-64
[20] Michael S, Jan H, Heinz M and Markus K 2014 Psychological Perspective on Motivation through Gamification p 4-5
[21] Ramine T, Markus L-R, Elena S and Wendy H 2017 An Investigation of Player Motivation in Eyewire, a Gamified Citizen Science Project *Computers in Human Behavior* Vol. 73 p 538
[22] Wenhao D H, Tristan E J, and Seung-Hyun C H 2013 Impact of Online Instructional Game Features on College Students’ Perceived Motivational Support and Cognitive Invesment: a Structural Equation Modeling Study *Internet and Higher Education* Vol. 17 p 66
[23] Elisa D M, Florian B, Alexandre N T and Klaus O 2015 Towards Understanding the Effects of Individual Gamification Elements on Intrinsic Motivation and Performance *Computers in Human Behavior* p 9