



# Multiplayer mechanism design for soil tillage serious game

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## Abstract

The primary goal of Serious Games is not only for fun but also for a lesson. In learning the first stage of soil tillage using the mouldboard plow, a proper understanding is needed so that the soil tillage process will follow the needs of plant growth. The use of serious games as a study instrument for soil tillage is under digital game-based learning (DGBL). The problem of players, when playing serious games, is less motivated to play because the serious game system and scenario are less challenging. These challenges accelerate knowledge and experience when playing the games (user experience). The learning process of land management using the mouldboard plow can be optimized by referring to the Learning Mechanics Gaming Mechanics (LM-GM) model, which is based on multiplayer in serious games. This process can increase learning motivation and elevate the user experience. This research results a design concept of a learning mechanism and a game mechanism for a serious multiplayer game of soil tillage with a mouldboard plow. There are three types of learning mechanisms in conceptual and concrete components. Also, six-game mechanisms can be used as a reference for forming serious multiplayer games and increasing player motivation.

**Keywords:** Serious Game; Moulboard plow; Multiplayer; User experience; LM-GM.

## Introduction

A game has an element of entertainment and is enjoyable. However, by prioritizing specific purposes other than entertainment, a game can be used to facilitate other purposes such as training, advertising, simulation, and education [1]–[3]. This type of game is called a serious game. In this study, the concept of a serious game was used as a learning medium for soil tillage using a mouldboard plow. Previous studies on serious soil tillage games were often related to engagement, immersion, modeling, and optimization [2], [4]–[6].

The limited training media for farmers caused a lack of knowledge about agricultural machinery. In addition to training media that the community could not widely use, other inhibiting factors were the lack of facilitators and the distant location of facilitators and farmers, thus affecting the intensity of mentoring [8]. Based on recent developments, computer technology, often called computer-based training and lecture-based computers, replaced traditional training and learning media, even in agriculture [7], [8].

The use of serious games as learning media has proliferated, including in agriculture. The single-player concept in serious games prioritizes interactivity but not the social aspect. The social aspect encourages interactivity with other players and the game system itself. In the concept of learning, group learning is considered more efficient and enjoyable than self-study [9], [10]. Referring to the fact that group learning is more enjoyable and efficient, this study used the multiplayer concept to design a serious game for soil tillage with the mouldboard plow.

## Method

### A. Soil Tillage Serious Game

The concept of a serious game that combines elements of experience and emotional freedom by actively playing will facilitate the learning process because there is an element of fun or entertainment, which coincides with the process of knowledge transfer and education [1], [11], [12]. Research on serious games for agricultural machinery included serious games in training to drive agricultural equipment because if done traditionally, it would require high costs, have a high risk of accidents, and have low efficiency [13], [14]. There were also studies in the form of

serious game concepts, such as on the effect of agricultural machinery trajectories on the soil [15], research on the shape of the mouldboard plow, and then comparing it with existing models to find the optimal form of the mouldboard plow [16]. There was also research with interactive concepts of 3D and dynamic web technologies and databases for agricultural machine virtualization [17]. Concerning XR (Extended Reality) technology, several agricultural studies have also been carried out for processing and management. The XR concept helped solve health problems during the Covid-19 pandemic, was relatively safe in the training process, and achieved a more immersive virtual environment in the XR environment [18].

Investigating various models in soil tillage is to find the most suitable tillage process for plant growth. The Fruchterman-Reingold algorithm described the relationship between conservative and conventional tillage, which was influenced by friction, depth, number of passes, time, bulk density, and soil penetration resistance. The study lasted four seasons and showed that conventional tillage was greater than conservative methods [19]. The modeling and field experiments aim to model Okra plants' growth using different tillage systems [20]. A polynomial function was modeled to represent the porosity of the soil so it could reach ready-to-plant porosity [21], and an optimization process was carried out with NSGA II in the concept of serious game engagement [5].

### **B. Multiplayer Serious Game**

The concept of collaborative learning using a game refers to a multiplayer game. A game with a more specific goal is called a serious game, so when a serious game is made collaboratively among players, it is called a serious multiplayer game. Various aspects of multiplayer that need to be considered for the success of the collaborative process are the number of players, persistence, player suitability, interaction, and social aspects [22].

Collaborative learning, especially in mastering technology in the classroom or field practice, will run more effectively if done in groups. It can happen because joint learning goals are formed, with additional social aspects and competition to bring up new ideas and new experiences in the learning process [23], [24]. On the other hand, multiplayer can also facilitate the formation of positive attitudes and behaviors, such as cooperation, the presence of other participants, and excitement among participants [25], [26]. Therefore, Multiplayer Serious Games (MSGs), which combines the concept of Serious Games (SGs) with collaborative learning techniques, is an approach to improve a more profound experience in the game-based learning process. Also, it can be a solution to handling collaborative problems as an example for organizing and evaluating students' performance in learning [27], [28].

The preparation of the Mechanics Framework refers to Mechanics Dynamics Aesthetics (MDA), in which there are repeated steps so that the appropriate mechanical design will be seen through playtesting [29]. Mechanics describes the game's specific components and algorithms at the data representation level. Dynamics describes the behavior of the mechanics at run-time, starting with the input of all players and output over time. Aesthetics describes the emotional response a player wants to evoke when interacting with the game system. As a framework, MDA can be used for digital game design that focuses on entertainment but is less supportive of serious content. Another model that focuses on the integration of "serious content" is the Learning Mechanics Gaming Mechanics (LM-GM) model, which provides a graphical representation of the gameplay to build relationships between pedagogical components [30], [31]. The LM-GM is an effective model that supports the SG concept in design, analysis, and assessment. Soil tillage learning for multiplayer component representation still lacks the support of the LM-GM framework, so a game engine approach such as Unity can be used to develop engaging multiplayer learning experiences or write realistic roles and behaviors for gamers [32].

## **Results and Discussion**

### **A. Learning Design in Serious Game**

The LM-GM model in the perspective of Self-determination theory (SDT) is used to identify SDT components related to learning motivation in the context of digital game-based learning (DGBL) and evaluation of SDT components used in Learning Mechanics and Game Mechanics (LM-GM). Based on this analysis, the LM-GM and SDT frameworks in the concept of multiplayer games were generated that can help explore the essential components to increase player motivation in serious games.

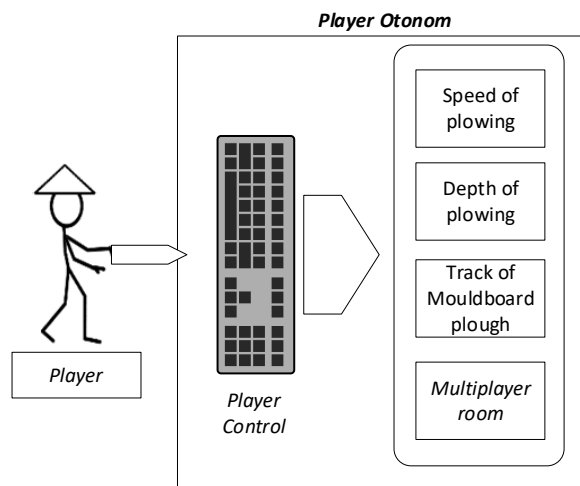
- Motivation and Self-determination theory (SDT)

In general theory, the motivation for the concept of DGBL is the concept of flow experience [30], [33], where the flow of the game can naturally lead to its own experience for the players. Flow experience theory defines as a complete process of cognitive absorption or player engagement, where individuals are not influenced by thoughts or emotions that are not related to the game process and have a specific purpose for inserting knowledge into players accompanied by repeated flows as a form of feedback to players, in which there is an evaluation of the game result.

The concept of player motivation is of two distinct types: intrinsic and extrinsic. Intrinsic Motivation (IM) is a motivation that arises because of interest and pleasure that comes from oneself. In contrast, extrinsic motivation (EM) is related to motivation provoked by external encouragement to achieve specific results. Intrinsic motivation can be triggered by a fun game [34], while challenges in the game process can stimulate extrinsic motivation.

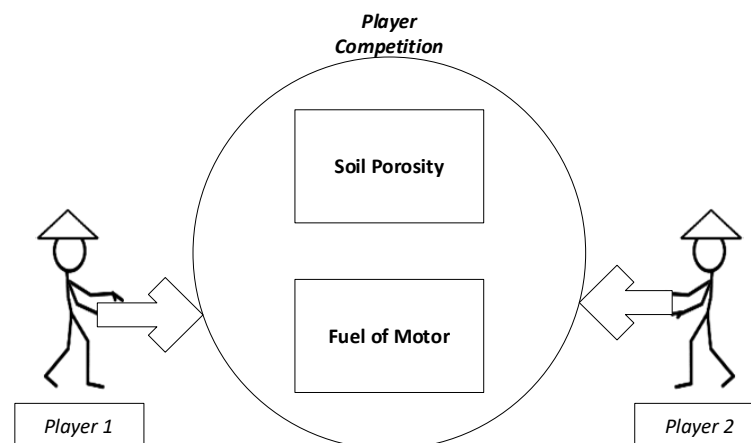
SDT's emphasis on IM can mean that bringing out fun is necessary for the SG's design, but EM must also be provoked through a challenge model that makes players curious and feels guided in the game. Students who learn the SDT concept can achieve flow experience faster and immersively related to the Cognitive Evaluation Theory (CET) concept, which is the core of SDT, where there are three things to achieve internal motivation growth that can be generated from the concept of extrinsic motivation, namely autonomy, competence and relatedness [35], [36]

Autonomy as a player is a concept that refers to the ability "to regulate oneself and regulate one's behavior" [37]. Thus in the game mechanism, there is control as a form of freedom for players to play and support behavior freely in the game. The mechanism that supports player autonomy is shown in **Figure 1**.



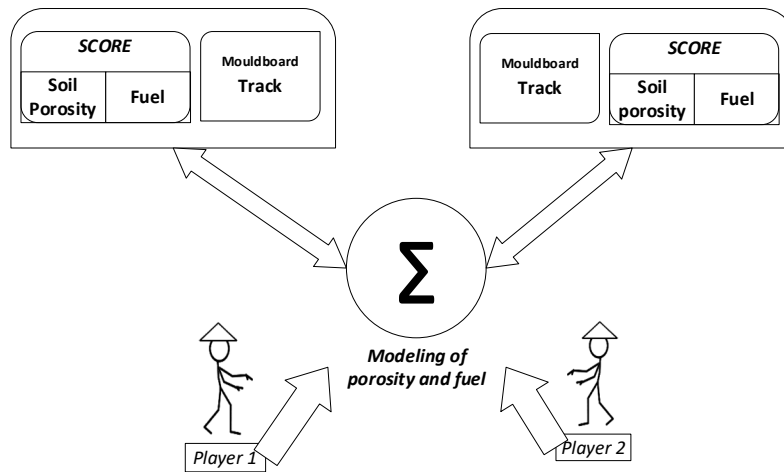
**Figure 1.** Diagram of the player autonomy concept in SG tillage using a mouldboard plow

Competence can be obtained because of "optimal engagement," meaning a challenge can be solved with optimal player involvement. The challenge is created and correlated with reality and social conditions. In the design of the SG tillage, competence is formed as a result of solving the fastest problem for fuel efficiency with the freedom of determining the player's autonomous behavior. The competency mechanism is also seen in competing with other players in the multiplayer space to achieve optimal porosity values and low fuel consumption, as shown in **Figure 2**.



**Figure 2.** Diagram of competition between players to achieve optimal porosity and fuel efficiency.

Player engagement is a social drive to achieve something and can be achieved if there is a connection and experience with the environment, either individually or with other people [38]. In the design of this SG tillage, the relationship formed is the use of land with the same shape, either in area or interfaces, thus having the same goal, ultimately creating competition, challenges, and experiences that naturally flow among players. The linkage between players exists in the user interface and modeling sides to achieve optimal porosity and fuel efficiency. For more details, see **Figure 3**.



**Figure 3.** Diagram of the relationship between players in the SG mechanism for soil tillage using the mouldboard plow.

- Correlation of motivation and autonomy in SDT

The type of motivation in SDT is distinguished based on the background or purpose of the action, which includes energy, direction, persistence, and the balance of these aspects, which are generally divided into three types, namely demotivation or lack of motivation, intrinsic motivation and extrinsic motivation [38].

For a profound experience to appear in a serious game, it is necessary to give freedom in the form of player autonomy so that they can develop a certain level of competence and have a social relationship with other parties. Students' ability to autonomy is related to the situation in the classroom (Reeve, 2002), meaning that the player's ability is influenced by the environment created in the game. Teachers can motivate students to have a certain autonomy to develop, feel more competent, and become more confident and creative. In games, especially SG, teachers can be created from the game flow that provides players with feedback and instructions. In addition, there are also automatic features of the game system to encourage an increase in player autonomy, called autonomous autonomy. The concept of SG, which still has a funny side, can be used as a link between the players' needs, interests, goals, abilities, and even culture so that motivation can emerge. Soil tillage using a plow can be developed specifically to design the game mechanism, which the LG-GM model supports. Models such as the LM-GM in the SG design are beneficial, allowing game mechanics to drive SDT components. The correlation between motivation and autonomy in improving the SDT model in SG tillage using the cassava plow is shown in **Table 4**.

**Table 4.** Design of motivational correlation to increase SDT.

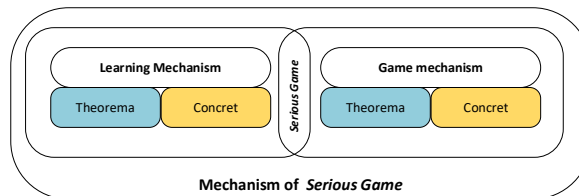
<b>Demotivation</b>	<b>Extrinsic motivation</b>				<b>Intrinsic motivation</b>
SG without clear scenario	Environmental regulations outside the SG	SG environmental demand	Identification of SG plot	Connection in SG plot	SG that blends with player
Motivation gap	Controlled motivation in certain condition		Naturally grown motivation		
Low player autonomy	←—————→				High player autonomy

**Table 4** shows that demotivation or lack of motivation occurs if the serious game does not have a precise scenario, causing a motivation gap between players and reducing player autonomy. The extrinsic motivation of players can be triggered when there are supporting rules and demands from the game environment. Meanwhile, naturally extrinsic motivation can grow when players can identify the plot in a serious game and feel connected to the game seriously. Intrinsic motivation will naturally arise from each player when the player can integrate with the serious game, so the concept of high engagement and immersiveness will directly foster that motivation.

**B. Multiplayer Serious Game Desain**

- LG-GM Model in Serious Game for Soil Tillage

The process of mapping pedagogical elements to entertaining gameplay using LM-GM refers to the SG concept, where pedagogy is an abstract element while gameplay elements are a substantial part [39]. Pedagogy and methods are theoretical and conceptual, while game mechanics are in the form of straightforward plots and algorithms, as shown in **Figure 4**.



**Figure 4.** General diagram of the relationship between the learning mechanism and the game mechanism.

In SG soil tillage using the mouldboard plow, the theoretical and conceptual part is learning how to properly cultivate the soil using the mouldboard plow, while the substantial part is the application of the theory in pedagogical concepts. The diagram in **Figure 5** represents the design of the learning mechanism that is abstract and concrete.

Leaning Mechanism		Game Mechanism	
Abstract	Concret	Abstract	Concret
Instructional	Repeatable	Fun	Game flow and cut scenes
Tutoring	Showed	Challenge	Action players
Participation	Active	Special behaviour	Level
General/Limitation	Activity	Reward	Score
Observation	Feedback	Interaction	QnA
Extraction	QnA	Optimistic	Unexpected plot
Planing	Discuss	Result	Acumulate score
Objective	Analisis	Story	Keep/remove
Hipoteses	Restrictions	Cooperation	Good Feedback
Motivation	Guiding	Optimal	Good Information
Ownership	Model	Feedback	Time limit
Responsibility	Simulation	Play Effect	Instruction
Explain	Evaluation	Simple Game	Game framework
Found	Result	Design	Gameplay
Competition	Group	Real	Appoiment
		Ownership	Movement control
		Game flow	Assesment
		Virality	Player Status
		Connected Information	Response
		Collaboration	Sharing score
		Competition	Group/room

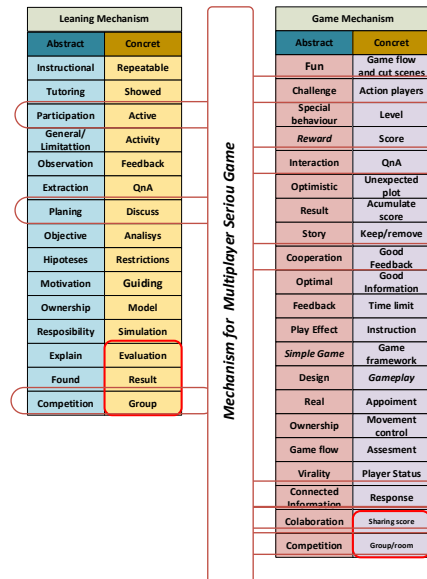
**Figure 5.** (a) Design of learning mechanisms that are abstract and concrete in SG tillage. (b). Design of game mechanics that are abstract and concrete in SG tillage

Based on the LG-GM model **Figure 5(a)**, the circled section emphasizes that the SG concept of soil tillage using a short plow has additional concrete components: assessment, results, and groups. In the assessment learning mechanism, it is necessary to know the abilities and results. Then the concept of group learning to compete and cooperate can also be raised. For the design of the game mechanism, there are also abstract and concrete elements, such as in **Figure 5(b)**. The area marked with a red box is needed to explain the concrete situation for the concept of collaboration and competition, where it is necessary to share results/scores and groups, primarily to support the game mechanics in serious games.

- Mechanism Serious Game for Multiplayer model

Multiplayer has the goal that SG can be played together to increase the challenge of the players and bring up a higher user experience [21], [40], [41]. Based on the LG-GM concept for SG tillage using a plow in Figure 6, to support multiplayer in terms of learning mechanisms for participation, planning, and competition is to be active in the game as a form of player participation, discussion with other players as a form of planning concept and also competition in certain groups as a form of the concept of competition.

**Figure 6** also shows the game mechanics where multiplayer can support the game's concept in terms of challenges, interactions, cooperation, connected information, collaboration, and competition. The game mechanism that supports multiplayer is player action. It consists of a challenge in the game, the interaction between players in the form of concrete questions and answers among players, information that arises due to interaction can concretely occur in collaboration to share experiences which is also part of cooperation when there is a question and answer among players. It is also a concept of collaboration value or scores obtained and the competition in the multiplayer group.



**Figure 6.** Multiplayer mechanism design in the LG-GM SG tillage concept.

Based on **Figure 6**, the marked connecting area is part of the mechanism of the serious game concept of tillage using the mouldboard plow so that the learning mechanism and game mechanism based on the LG-GM model can be achieved.

**C. The serious game multiplayer plot of soil tillage**

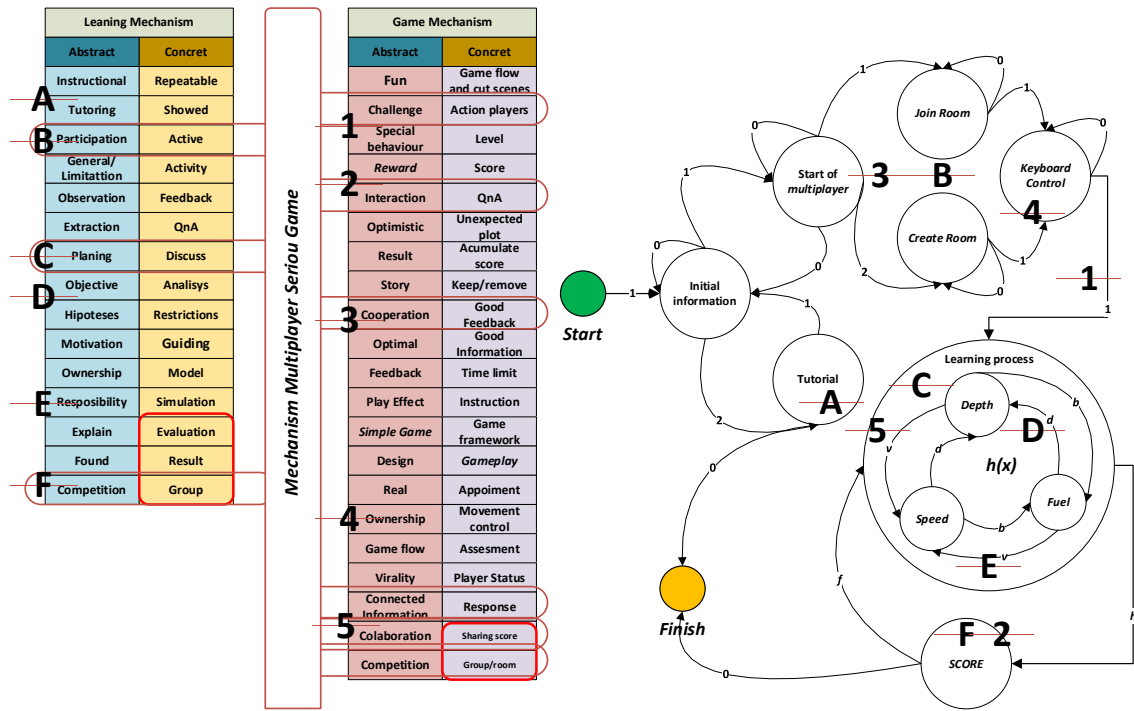
The SG plot shows the player's steps in running a serious game of soil tillage using the mouldboard plow. This plot is representative of gameplay in the form of HFSM (Hierarchical Finite State Machine), a representation of a serious multiplayer game mechanism for soil tillage using a mouldboard plow as shown in **Figure 6**.

The numbers and letters in Figure 7 show the correlation between the learning mechanism and the game mechanism in the serious game plot in the form of HFSM, with an explanation as shown in **Table 2**.

**Table 2.** Representation of learning and game mechanisms in HFSM multiplayer serious game tillage using mouldboard plow

Learning Mechanism		Game Mechanism		State/Transition (HFSM)
<b>A</b>	Repeated instruction	<b>1</b>	Challenge shown in Action players	Tutorial state, Transition from keyboard control state to learning process state
	Tutoring shown		Every level has a special behavior.	
<b>B</b>	Active participation	<b>2</b>	With a score to reward and shown interaction with QnA	Join room state or create room state, control a keyboard state and score state
		<b>3</b>	Make cooperation using good feedback	
<b>C</b>	Planning with a discussion	<b>4</b>	Ownership of movement	Keyboard control state and

	<i>Learning Mechanism</i>		<i>Game Mechanism</i>	<i>State/Transition (HFSM)</i>
<b>D</b>	Objective to analysis, hypotheses about restriction		control	learning process state
<b>E</b>	Responsibility to use and finish simulation	5	Connect information and give a response, collaboration for sharing a score	learning process state
<b>F</b>	Competition in group	5	Competition in group room multiplayer	learning process state and score state



**Figure 7.** Representation of the multiplayer serious game mechanism for soil tillage with the game flow design using HFSM

$h(x)$  is a simple linear equation to model the relationship between plow blade depth, drive motor speed and required fuel. The value of the  $h$  transition in HFSM indicates the transition to enter the game score state.

$$h(x) = 0.000022921 (x_1) + 0.000000701 (x_2) + 0.000035401 \quad (1)$$

Note :  $x_1$ =Depth (cm),  $x_2$ =Speed (cm/s),  $h(x)$ =Fuel Consumption (l)

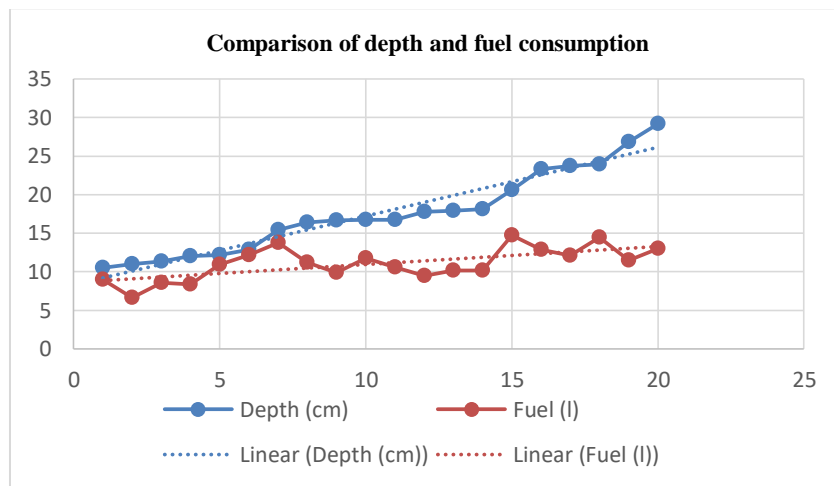
Based on equation (1) which is the result of previous research [42] ], for a simple linear equation of game flow in the state learning process, data is generated for 20 times with random speed conditions between 500 cm/s to 1500 cm/s and depth conditions between 10 cm to 30 cm then the experimental data is generated as represented in **Table 3**.

**Table 3.** The test results of the serious game flow in the state learning process

Depth ( $x_1$ ) cm	Speed ( $x_2$ ) cm/s	Fuel consumption ( $h(x)$ ) liter
10,54742248	891,2179128	0,000901902
10,99305016	533,0741993	0,000661058

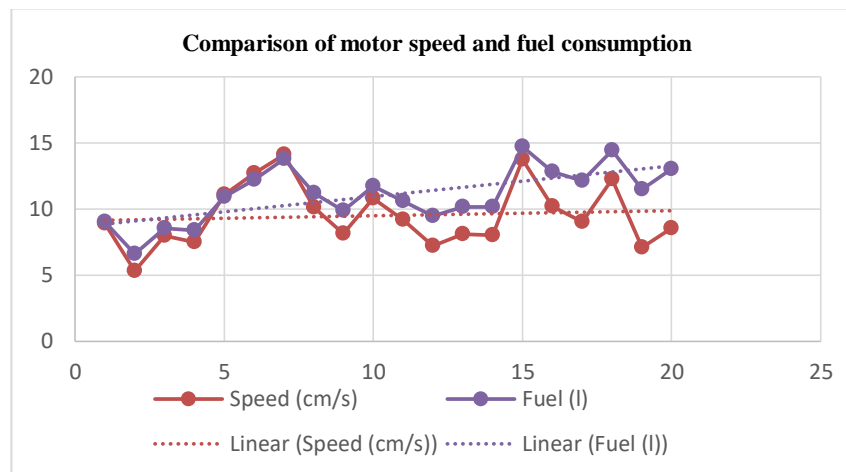
Depth ( $x_1$ ) cm	Speed ( $x_2$ ) cm/s	Fuel consumption ( $h(x)$ ) liter
11,31445796	798,9200858	0,000854783
12,01849832	749,4925928	0,000836271
12,18894679	1108,702521	0,001091984
12,85119472	1269,159361	0,001219644
15,39188028	1412,507274	0,001378366
16,404056	1010,576803	0,001119813
16,65463683	813,670641	0,000987525
16,70570997	1078,411131	0,001174279
16,70597701	916,9173922	0,001061078
17,76097464	720,083638	0,000947279
17,91748782	809,9238103	0,001013844
18,13496246	803,3233465	0,001014202
20,64360757	1373,684656	0,001471526
23,28770739	1018,779769	0,001283343
23,74015521	902,1926145	0,001211986
23,92010372	1225,050865	0,001442434
26,85429123	711,0291994	0,00114936
29,18528173	855,0474971	0,001303745

**Table 3** shows that the more profound the plowshares, the higher the fuel consumption, and the higher the motor speed, the higher the fuel consumption. To simply reading the graph, the value of fuel consumption is multiplied by 10,000, and the speed value is divided by 100, as shown by the diagram in **Figure 8**.



**Figure 8.** Comparison graph when the depth increases, the fuel consumption also increases.





**Figure 9.** Comparison graph when the motor speed increases, the fuel consumption also increases.

**Figure 8** and **Figure 9** show that the increase in fuel consumption is directly proportional to the depth of the plow blade and the speed of the mouldboard plow motor. From **Figure 9**, it is interesting that the reason fuel consumption increase is identical to the speed of the plow motor is that speed changes affect the power demand of the motor, which eventually increases fuel consumption.

### Conclusion

Based on the analysis that refers to the LM-GM model, it can be concluded that several components need to be added to the learning mechanism, namely: The concept that players can explain is a substantial part of an evaluation of learning. The concept that the player finds something which is a concrete form of the player's learning outcomes. The concept of competition among students within the scope of study groups.

Meanwhile, in terms of game mechanics, it is necessary to add the concept of collaboration in the game in the form of knowing each other's scores (sharing scores) and the concept of competition among players that is competition with other players in a multiplayer room.

In addition to the addition of these types of components, not all types of components from LM-GM can be used as a serious multiplayer game model. Three components of learning mechanics and six components of game mechanics make up the mechanics of serious multiplayer games. The components that can be used as a multiplayer serious game model from a conceptual or abstract point of view are participation, planning, and competition. In contrast, for the game mechanism, the concepts used are Challenge, Interaction, Cooperation, Connected Information, Collaboration, and Competition. The concept is in an abstract form supported by concrete components in the learning mechanism, namely active learning, discussion in learning, and group formation in competition. While the concrete side of the game mechanism is the action of players in facing challenges, questions and answers in the game, good feedback in the game, responses and information between players in the game, and scores that can be seen by other players in the game room and competition between players.

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