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A 3D Multiuser Virtual Learning Environment for Online Training of Agriculture Surveyors

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Abstract

Aim/Purpose	This research proposed a 3D multiuser virtual learning environment (3DMUVLE) educational game design framework by combining ATMSG, ADDIE, E-Simulation, and 3D Open Simulator Technology Architecture. This paper focused on a case study of online training for food crops productivity data surveys.
Background	The conventional online training still lacks engagement, immersion, and curiosity aspects, which decreases learners' learning seriousness because the instructors and participants do not meet directly. Integration of 3DMUVLE and gamification in online training has a good potential to tackle the issue.
Methodology	This research applied the Design Research Method (DRM) to propose a 3DMUVLE educational game design framework. The proposed framework was applied in training that involved 30 participants (first group), and the result was compared with that of 30 other participants (second group) who studied using the conventional method, which was an e-book and web-based learning. Authors compared the perceived usefulness and heightened enjoyment in using the proposed 3DMUVLE using linear regression analysis on HMSAM model.
Contribution	Through statistical tests on the case study data, this research indicated that the 3DMUVLE resulted in better knowledge gain.
Findings	Some important findings in this paper include (1) the development steps of a 3DMUVLE educational game design framework for online training of food crops productivity data survey; (2) statistical analysis result that the proposed

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3DMUVLE lead to better knowledge gain, enjoyment, curiosity, immersion, and usefulness aspects; (3) the statistical analytic also showed that enjoyment and perceived of usefulness factors represented the strongest variables that influenced behavioral intention to use.

Recommendations for Practitioners — The 3DMUVLE is suggested to produce better knowledge gain, yet it still has to be proven further through similar statistical analysis in real field survey scenarios.

Recommendations for Researchers — The proposed 3DMUVLE can be adapted to other domains. Pleasing features in the game can be improved, such as quality of instruction in the simulation, in the hope that these will increase engagement and knowledge gain. Voice communication among users and instructors to improve interactivity may also be introduced.

Impact on Society — 3DMUVLE potentially offers better knowledge gain that can be applied in various fields of online training.

Future Research — An immediate future research includes a development targeted for smartphone platform, in Virtual Reality (VR) or non-VR mode. VR improves immersion aspect further but is more complicated to perform. Smartphone is relatively cheaper than a computer and more accessible by more people. Training using a smartphone-based 3DMUVLE can be carried out in wider scenarios.

Keywords — 3D, virtual learning environment, educational game, online training

INTRODUCTION

Despite bringing about many advantages, online training causes less engagement, curiosity, focus, and immersion, which decreases learners' learning seriousness (Hara & Kling, 2001). It happens because instructors and participants do not meet directly. This problem can be solved using game and gamification that have been proven to increase learning behavior (Bunchball Inc., 2010; Chittaro & Buttussi, 2015; Hamari, Koivisto, & Sarsa, 2014; Ibanez, Di-Serio, & Delgado-Kloos, 2014). Game and gamification use two-way communication that provides feedback to learners directly (Boyle, Connolly, & Hainey, 2011; Werbach & Hunter, 2012). It increases learners' motivation due to the fear of losing and the expectation of obtaining reward from the system.

Another challenge in online self-training is how to teach learning material that are 3D based fieldwork simulations. A solution to the problem is 3D virtual world simulation (Susi, Johannesson, & Blacklund, 2007). It can be shown that the real-world experience situation is better than answering multiple-choice (Garris, Ahlers, & Driskell, 2002). Many researchers concluded that simulation games provided better knowledge than conventional methods (Blas, Bucciero, Mainetti, & Paolini, 2012; Chittaro & Buttussi, 2015; Getchell, Miller, Nicoll, Sweetman, & Allison, 2010; Kilteni, Bergstrom, & Slater, 2013; Patel & Vij, 2012). In addition, 3D virtual world simulation can overcome distance, space, and human resource barriers, so the training can be more efficient, secure, and comfortable (Corti, 2006). Therefore, the integration of games, gamification, and 3D simulation in the online training has a high potential to solve major problems faced in training of field agriculture surveyors.

However, most studies do not provide enough information about how to design and implement 3D gamification (Clark, Tanner-Smith, & Killingsworth, 2015; Sitzmann, 2011). Also, certain authors still have issues about reliability and validity, such as the number of students that did not receive educational intervention (Hays, 2005), time management in experimental and control groups, and the validity of research instruments (Randel, Morris, Wetzel, & Whitehill, 1992). This research solved all the foregoing issues by proposing a new game design framework by combining Activity Theory-based

Model of Serious Game (ATMSG), ADDIE model (Analysis-Design-Develop-Implement-Evaluate), E-Simulation, and 3D Open Simulator Technology Architecture.

RELATED WORK AND MOTIVATION

In normal conditions, before collecting data from the fields, a surveyor trains herself with the required knowledge and skills. In Indonesia, organizing a training session implies inviting many surveyors from many remote places, hence it incurs high cost. Due to budget limitations, some of such training is canceled. Training is replaced by simply distributing e-books to the affected trainees via e-learning website. E-Simulation emerges as better alternative than this e-book distribution. Specifically, virtual learning based on 3D environment can provide the effect of realism to support training and simulation, as was done by Ney, Goncalves, and Balacheff (2014). Simulation practice also needs to be interactive with clear sequence and logic, as has been done implemented in simulation game-based 3D by Chittaro and Buttussi (2015).

Game-based learning is used to encourage learning activities by building on motivation, engagement, knowledge, and challenge through various technologies to achieve learning objectives (Liu & Chen, 2013; Romero, Usart, & Ott, 2015; Villagrasa, Fonseca, & Durán, 2014). Implementation technology in learning also improves learning and skill development while entertaining the user (Ricciardi & De Paolis, 2014). Technology such as virtual world is designed to offer a real-world learning experience by providing real-time communication tools, interactive capabilities, and collaborative empowerment (Dickey, 2005; Kotsilieris & Dimopoulou, 2013).

Research involving 3D multiuser virtual learning environment (3DMUVLE) has been applied in several fields of science, such as a preliminary study of the current research by Achiruzaman and Rosmansyah (2016); Callaghan, McCusker, Losada, Harkin, and Wilson (2013) in the electrical circuits learning; Crespo, Aguilar, Escobar, Velazco, and Sanz (2013) in the virtual university campus; Torre et al. (2013) in the remote laboratories learning; Božović, Milošević, Blagojević, and Mitrović (2014) in the medical learning; and Ntokas, Maratou, and Xenos (2015) in the information security learning. Other research was conducted by Patel and Vij (2012) in the spatial learning simulations; Chittaro and Buttusi (2015) in the safety of flight simulation game; and Getchell, Miller, Nicoll, Sweetman, and Allison (2010) in the game of historical sites exploration. Yasar and Adiguzel (2010) discussed the potential of the integration of a web-based learning management system (LMS) and 3D virtual world (SLOODLE) to increase self-learning ability, as discussed also by Guomin and Jianxin (2010). Martenstyaro and Rosmansyah (2016) had conducted similar research about the 3D virtual world and web-based LMS integration using SLOODLE, but they did not include participants' knowledge gain evaluation nor any proposed gamification design.

THEORETICAL BACKGROUND

GAME, GAMIFICATION, SIMULATION GAME, AND VIRTUAL WORLD

Salen and Zimmerman (2003) defined a game as "a system in which players engage in artificial conflict, defined by rules that result in a quantifiable outcome". Creating an engaging game is a significant challenge that involves the conception and design of rules to immerse players in fun activities (Schell, 2008). The game design balances the use of a set of elements and rules that when brought into practice provoke emotional responses in players (Hunicke, LeBlanc, & Zubek, 2004; Schell, 2008). When game design elements are used in non-game contexts it is referred to as gamification (Deterding, Khaled, Dixon, & Nacke, 2011). Further, when a player has an opportunity to experience a certain situation in a real-life scenario, through the combination of game characteristics (e.g. tasks and rules), it is called simulation (Raser, 1969).

When a computer-based simulated environment is populated by many users it is often referred to as a virtual world or virtual environment. Each user can create a personal avatar, and simultaneously and independently explore the virtual world, participate in its activities and communicate with others. All virtual worlds possess the qualities of persistence and interactivity. This enables users to explore the inherent benefits of socialization and allows them to study human nature and users' abilities.

Open Simulator is an open-source multi-platform with a multiuser 3D application server (OpenSimulator, 2019). It can be used to create a virtual environment that can be accessed through a variety of clients, on multiple protocols.

Food Crops Productivity Data Survey

Food crops productivity data survey is an important survey conducted by Statistics Indonesia (BPS-Government Agency) in Indonesia. The period of data collection is sub-round (quarterly). Productivity data collection is conducted at the time of harvest using direct measurements in a plot square of 2.5 meters by 2.5 meters. Food crops include rice, corn, soybeans, peanuts, cassava, and sweet potatoes (BPS – Indonesia, 2015).

Other data which are also collected in this survey include types of land, planting, and cultivation system (especially rice), types of productivity-improvement activities, amount of seed used, type of seed varieties used (especially rice and corn), amount of fertilizer used, information about pest control, fertilizer, and qualitative information related to productivity (BPS – Indonesia, 2015).

So far, the problem area has been briefly identified and a gamified virtual world has been prepared for simulation. Another field to combine is "how to integrate knowledge into the virtual world", which is discussed in the following section.

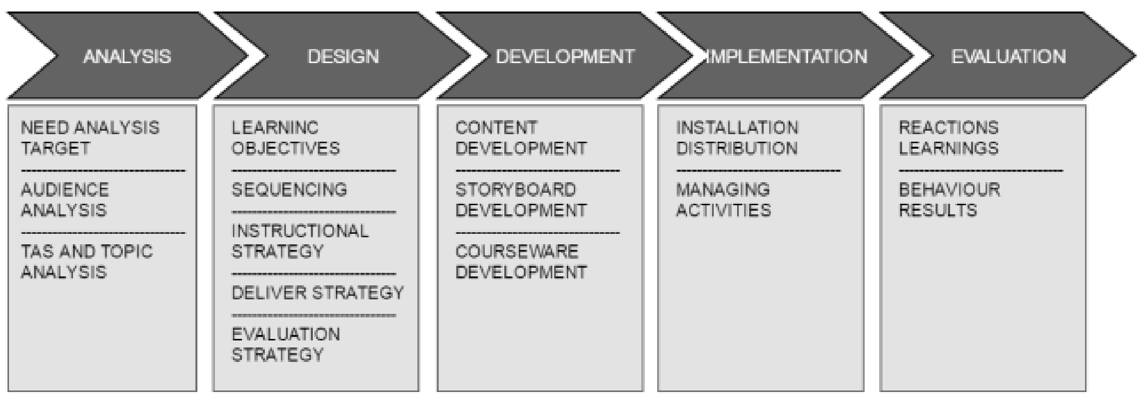


Figure 1: ADDIE Method

ADDIE Method

ADDIE refers to Analysis, Design, Development, Implementation, and Evaluation, as shown in Figure 1. ADDIE is an instructional design methodology used as a guide to help designers or developers in designing and developing education and learning programs (Aldoobie, 2015). This model provides a dynamic and flexible guideline where the results of the evaluation of each phase may lead back to the previous phase. The analyze phase includes collecting information by using interviews, questionnaires, or surveys about the knowledge, skills or attitudes the learner needs to be taught to achieve learning goals. Next is the design phase where the designer creates a master blueprint of how the learning program will be delivered. The designer needs to plan an instructional strategy to decide and select the right method(s) of delivery. In the development phase, designer integrates technology with actual learning materials that will be used during the learning program. The implementation phase represents transforming entire planning into action. This phase includes preparing some training the instructors, the learners, and preparing a learning environment. The final phase is the evaluation phase. In this phase, it is very important to evaluate each step in order to make sure that the learning program meets learning objectives.

Activity Theory-based Model of Serious Game (ATMSG)

Once the ADDIE method has been prepared, the Activity Theory-based Model of Serious Game (ATMSG) is used to design a serious game (Carvalho et al., 2015) using activity theory (Engestorm, 1987) simultaneously in time, in the planned virtual world. The ATMSG model represents different low-level components from serious game applications and how the components are connected, as shown in Figure 2. There are four main activities involved: the gaming activity, the learning activity, the intrinsic activity, and the extrinsic activity. The gaming activity refers to game mechanics by game researcher and designer. The learning activity describes the learning objective and transferring skills such as critical thinking, creativity, problem-solving, etc. The intrinsic activity refers to learning content, game design, and game production. The extrinsic activity represents the impact of game in learning.

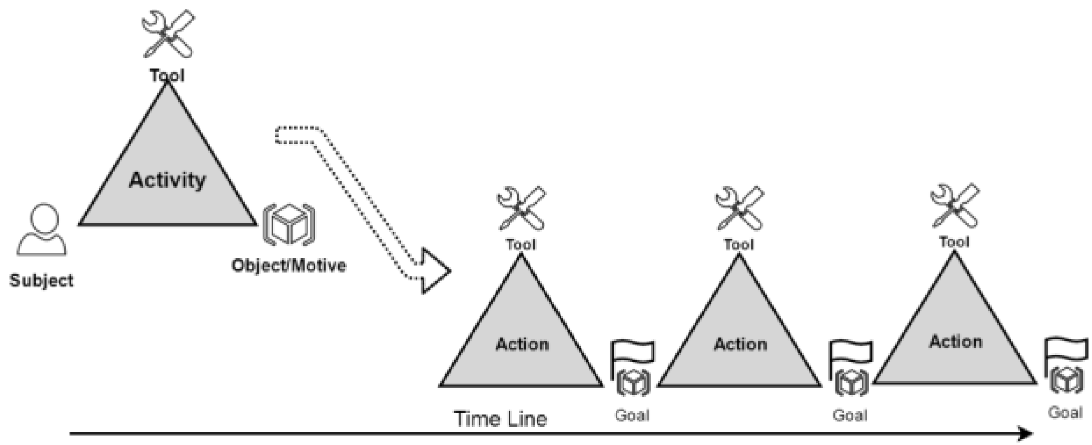


Figure 2: Activity Theory

Description of Experiment

The research method adopted in this research was the Design Research Methodology (DRM) Framework (Blessing & Chakrabarti, 2009), which defines four iterative stages: Research Clarification (RC), Descriptive Study I (DS I), Perspective Study (PS), and Descriptive Study II (DS II). Every stage on DRM is mapped and described in the following subsections, as shown in Figure 3. In this research, the output of each stage is adjusted to the needs of the research.

Research Clarification

In this stage, evidence or indications that support assumptions in order to formulate a realistic and worthwhile research goal were identified. Based on three research objectives for this case study, hypotheses were structured as follows:

> H1: 3DMUVLE produces better knowledge gain to the participants than the conventional method.
> H2: 3DMUVLE produces better motivation gain to the participants than the conventional method.
> H3: The most important factors in determining a user to use the proposed 3DMUVLE are usefulness and curiosity.

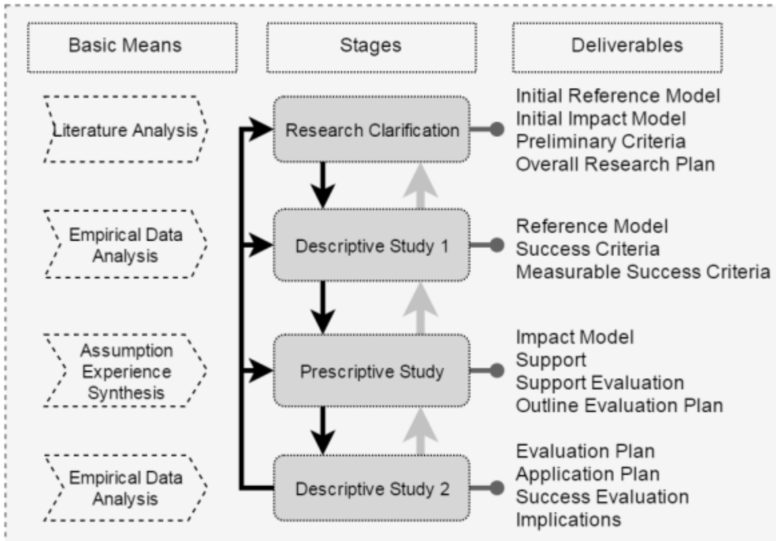


Figure 3: Design Research Methodology (DRM)

DESCRIPTIVE STUDY I

The literature was reviewed for more influencing factors to elaborate on the initial description of the existing situation. A reference model was created to describe this situation, as shown in Figure 4. Canceled training and simulation and low motivation on training which influenced knowledge was an initiative to draw the reference model.

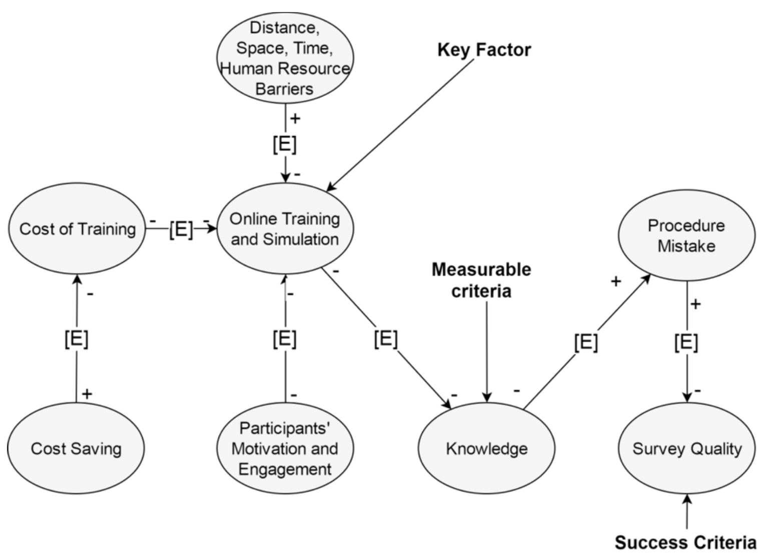


Figure 4: The Created Reference Model

Success criteria refer to the ultimate goals, to which the research intends to contribute (Blessing & Chakrabarti, 2009). Survey quality was made as the main success criterion that is consistent with the vision of statistics Indonesia, which is a pioneer of reliable statistical data for everyone (BPS – Indonesia, 2015). Success criteria were not measured in this research. Consistent with the defined hypotheses, knowledge will serve as a measurable success criterion.

PRESCRIPTIVE STUDY

In this stage, experiences and proofs that can increase support in our research were involved. The deliverables from this stage are (1) an impact model based on literature study and (2) support in the implementation of the impact model. Figure 5 shows the impact model. In this research, support is a 3D simulation game framework as a guide in managing online training.

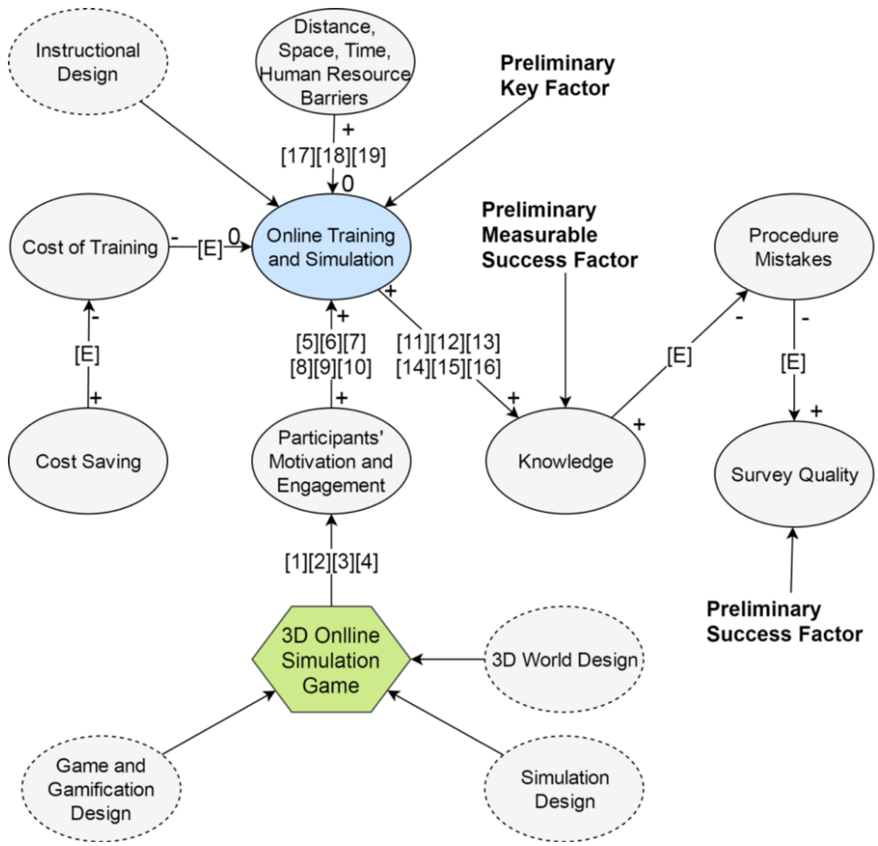


Figure 5: The Impact Model

Support 1: Proposed framework

Gartner's reports stated that many gamification-based solutions fail because, mostly, they have been created on a whim or mix bits and pieces of game components, without a clear and formal design process. The application of a definite design framework aims to be a path to success (Mora, Riera, Gonzalez, & Arnedo-Moreno, 2015). In addition, gamification must be aligned to the business objective (external and internal), enterprise structure, and specific technology. Therefore, existing gamification frameworks most likely require modification to fit a particular organization's needs.

The authors had developed a framework that fitted our organization's specifications. The framework combined ATMSG, ADDIE method of instructional design, E-Simulation, and Open Simulator Architecture (OpenSimulator, 2012). ATMSG was adopted since it has been compared with other game frameworks based on 10 features (Carvalho et al., 2015). As shown in Table 1, Carvalho et al. (2015) stated that ATMSG has the most complete features than the others.

The final framework for developing the 3DMUVLE is shown in Figure 6

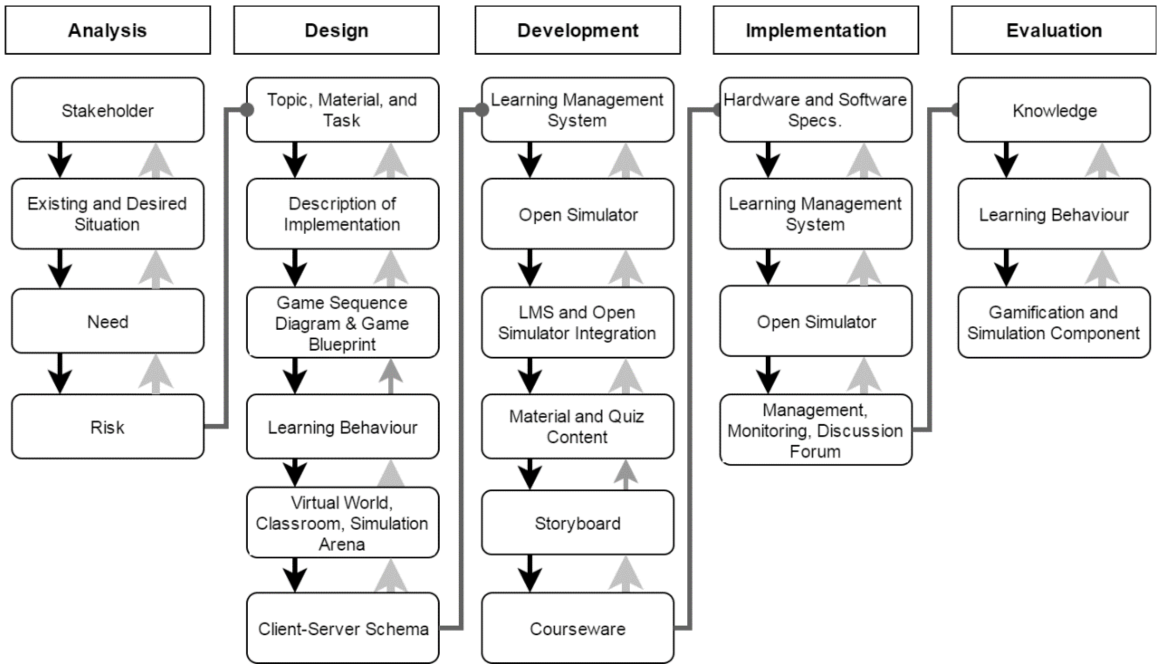


Figure 6: The Proposed Framework

Table 1: Game Design Framework Comparison

Feature	LM-GM	MDA	HABS	Machination	GOP	4Dimensional	Experiential Gaming Model	Game Based Learning	ATMSG
Relationship between game elements and diagram	A	*	*	*	*	*	*	*	A
Connection concrete mechanic and high-level educational objective	U	*	*	*	*	*	*	*	A
Support reasoning educational element in serious game	*	*	*	*	*	*	*	*	A
Interaction between gaming and learning	*	*	U	*	*	*	*	*	A
Relationship between difference layer of implementation of the game	*	A	A	*	*	*	*	*	A
Description low-level components	*	*	*	A	A	U	U	U	A

Feature	LM-GM	MDA	HABS	Machination	GOP	4Dimensional	Experiential Gaming Model	Game Based Learning	ATMSG
Describing game in general	*	A	A	U	U	*	*	*	A
Educational value of serious game	*	*	*	*	*	A	*	*	A
Linking experiential learning and gameplay theory	*	*	*	*	*	*	A	A	A
Serious game fits an educator's need	*	*	*	*	*	*	*	*	A

** = Not Assessed, U = Unavailable, A = Available*

Support 2: Application of the proposed framework

In this section, only the most relevant parts of the proposed framework are described, including (1) Need Analysis, (2) Topic, Material, and Tasks Design, (3) Game Sequence Diagram, (4) Description of Implementation, (5) Game Blueprint, (6) Simulation Arena Design, and (7) Implementation of the game.

Need Analysis. Based on the need analysis, a table for the description of needs was created. Table 2 shows such a table for food crops productivity survey training, which was the case study.

Table 2: Description of Needs

No	Scope	Description
1	Audience	The audience is expected to have basic knowledge about food crops productivity data collecting survey
2	Aim	Participants (learners) learn in a virtual class that uses pre-test and post-test to assess their knowledge gain. In addition, the authors use the motivation variable to assess enjoyment, engagement, and learning focus
3	Objective	A virtual fieldwork simulation that is supported by communication between an instructor and participants
4	Substance	- Started by a pre-test - Learning scenario (read, remember, and answer) divided into six sessions - Finished by a post-test - Participants give feedback in the questionnaire
5	Setting	The learning process (read, remember, answer) is conducted in a virtual classroom, while virtual fieldwork simulation is conducted in a virtual field
6	Gaming	Each page of the learning material and each correct answer will give points to the participants. They are motivated to achieve the highest points
7	Intrinsic Instruction	A learning environment that produces enjoyment, curiosity, focused immersion, and easy-to-control aspects

Topic, Material, and Task Design. The task was divided into three, namely, learning material, quiz, and simulation. Table 3 shows the task and topic generally. It was taken/referred from food crops productivity data collecting manual (BPS – Indonesia, 2015). The authors rearranged and divided it into six sessions.

Table 3: Description of Task and Topic

Task	Topic
Pre-test (13 questions)	All about food crops survey
Read material (13 slides) & quiz	Data collecting and sampling methodology
Read material (9 slides) & quiz	Concept and definition
Read material (23 slides) & quiz	Household updating (SUB-P)
Read material (21 slides) & quiz	Filling of harvest data 1 (SUB-S questionnaire)
Read material (14 slides) & quiz	Filling of harvest data 2 (SUB-S questionnaire)
Read material (5 slides) & quiz	Filling of harvest data 2 (SUB-S questionnaire)
Fieldwork simulation (instruction)	Harvest plot area sampling (step by step)
Fieldwork simulation (instruction)	Marking boundary of sampled area by setting marker posts (step by step)
Post-test (13 questions)	All about food crops survey

Game Sequence Diagram. The output in this stage is a Game Sequence Diagram (GSD). The GSD uses a Unified Modeling Language (UML) diagram that describes game process nodes from beginning to end which are arranged horizontally. Figure 7 shows such a diagram.

Figure 7: Game Sequence Diagram

Description of Implementation. Description of implementation is a narration of the game that includes the description of the game, learning, and instructional elements for each node in the GSD. The final description of the implementation is shown in Table 4.

Table 4: Description of Implementation

Game Nodes	Gaming	Learning	Instruction
1. Rules of Game	-	-	Participants read training instructions
2. Pre-test	Participants complete the 13 questions before they perform training	Participants measure their initial knowledge	-
3. Participants training, they read learning material and quizzes (session 1 – 6)	Participants read the material in the presenter slide format. They get a point for each page they read. Participants complete the quiz at each session. If the answer is right, they get a point. Participants must complete the previous session before they continue to the next session	Participants understand all material step by step. Participants learn survey instruments, concepts and definitions, consistency, and question logic	By using one layer for each question, participants were able to increase their learning focus.

Game Nodes	Gaming	Learning	Instruction
4. Visit the virtual field to conduct sampling in determining the sample harvest area plot (with simulation)	Participants determine sample harvest area plot through simulation and they get 90 points maximum	Participants understand the sampling method in determining the sample harvest area plot step by step.	A good user interface will increase participants' interest. Clear instruction will increase participants' performance.
5. Visit virtual field to conduct installation of harvester (with animation)	Participants get 200 points maximum if all tasks completed	Participants understand the position of harvester	A good animation will increase fun and enjoyment
6. Post-test	Participants complete 13 post-test questions	Authors measure how training give impact to participants' knowledge gain	-
7. Reward	The incorrect answers lead to low total points and vice versa. The points increase the opportunity to get the reward. The reward gives motivation to participants to do all tasks better.	Each step of training gives feedback to participants such as points or corrections to the wrong answer. Those make participants always learn from their mistakes	-

Game Blueprint. When the game sequence diagram and description of the implementation are completed, a game blueprint (GB) is in order. The GB is the combination of the game sequence diagram with game, learning, and instructional elements. The GB definition is shown in Table 5. All of the game components were taken from the ATMSG taxonomy (Carvalho et al., 2015).

Table 5: Game Blueprint

		Pre-test	Read Material and Quiz (session 1 – 6)	Simulation of Harvest Plot Area Sampling	Simulation of Harvester Installation	Post-test
Gaming	Action	Answer Question, Visit, See Performance Evaluation	Answer Question, Visit, See Performance Evaluation	Answer Question, Visit, See Performance Evaluation	Customise, Move	See Performance Evaluation
	Tool	3D Space	3D Space, Point, Score	3D Space, Point, Score, Role Play	3D Space, Score, Role Play	Point, Score, Status Levels, Leaderboard
	Goal	Complete Quest	Complete Quest, Maximize Score	Complete Quest, Maximize Score	Maximize Score	Maximize Performance
Learning	Action	Relate, Choose, Compare, Calculate	Find, Relate, Choose, Compare, Calculate	Identify, Relate, Choose, Compare, Calculate	Match, Explore, Relate	-
	Tool	Test, Task	Test, Task, Media Presentations	Test, Task, Media Presentation, Animation, Simulator	Task, Media Presentation, Animation, Simulator	-
	Goal	Understanding	Understanding	Understanding, Real Experience	Understanding, Real Experience	-

Intrinsic Instruction	Action	Present Material, Present Quiz Assess Performance	Present Material, Present Quiz Assess Performance	Present Material, Repetition, Assess Performance, Demonstrate	Present Material, Repetition, Assess Performance, Demonstrate	Give Reward
	Tool	Question & Answer	Question & Answer, Performance Measures	Question & Answer, Simulators, Performance Measures	Simulators, Performance Measures	Performance Measures
	Goal	Asses Performance	Asses Performance, Provide Feedback	Asses Performance, Provide Feedback	Asses Performance, Provide Feedback	Assess Performance

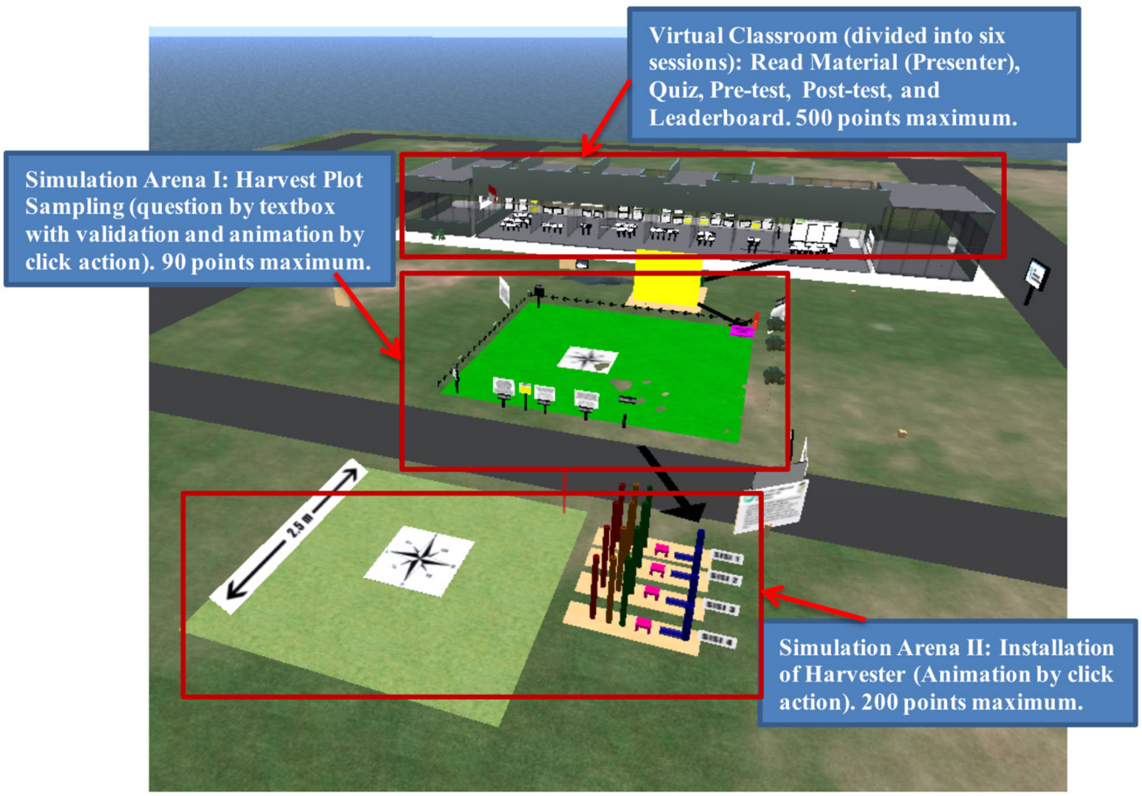


Figure 8: 3D Simulation Game Arena

Simulation Arena Design. In a 3D simulation game, the arena design is very important. Referring to the Open Simulator configuration (OpenSimulator, 2018), a virtual world is named a region (island) which has attributes such as size (default: 256x256 m^2), port number (default: 9000), and position (default: x=1000, y=1000). The design in this stage gives consideration in preparing server capacity. Figure 8 shows the 3D Simulation Game Arena in this paper.

Based on our own experience, there are some considerations in the 3D object design and placement, namely, (1) The distance between objects should not be far apart. A long-distance will tend to reduce motivation and make it difficult for learners to navigate; (2) If necessary, a teleport facility can be used to overcome the distance problem; (3) All locations should be provided with a set complete instructions and direction/arrow so that the learners find it easy to complete all game stages.

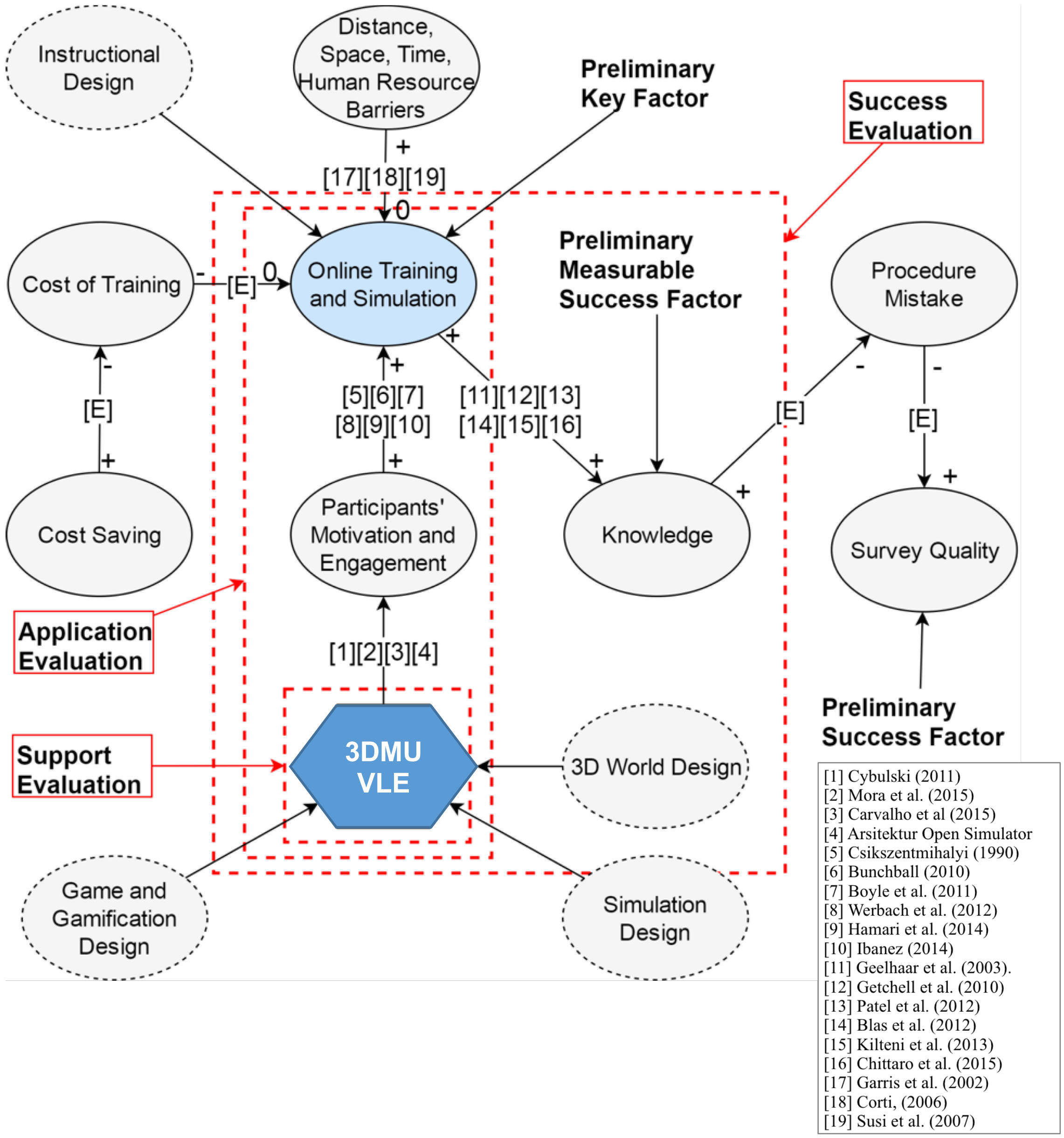


Figure 9: Support, Application, Success Evaluation

Implementation. The server application (Open Simulator 0.7.4) was installed on Ubuntu Server 12.04 OS in Virtual Private Server (VPS). The authors also installed MySQL database (Version 5.5.52), Apache Server (Version 2.2.22), and Moodle LMS (Version 2.5.9). The learning materials, quizzes, and simulations were installed in the server application, so the participants join training in the 3DMUVLE fully. Before joining the training, they first installed a Singularity client application (Version 1.8.5) on desktop PCs or notebooks. The minimum client hardware specification is 3 GHz processor x86, 4 GB RAM, 1024x768 pixels screen resolution, and an NVIDIA GTX950 or ATI/AMD 5000 series graphic card.

Descriptive Study II

The final stage in this research is an evaluation of the implementation of our support. The evaluation contains three types of evaluations, those are:

1. Support Evaluation, to measure the suitability of the Proposed Framework
2. Application Evaluation, to measure the Motivation Gain and User Acceptance Model
3. Success Evaluation, to measure the Knowledge Gain

Figure 9 shows the relationship between the support, the application, and the successful evaluation of the proposed framework in this paper.

RESULT AND DISCUSSION

The implementation of survey training in Statistics Indonesia is a mixture of face-to-face and online self-training by making use of mainly PDF files. This learning method causes the surveyor trainees to exhibit less motivation, interest, immersion, and concentration. In addition, field simulation is removed and replaced by guidebooks. This constrained situation makes it difficult for the trainees to enhance their knowledge and skills and also to apply them into actions in the real field.

Gamification is considered as a solution to increase enthusiasm and desire to learn. Moreover, the 3D virtual environment also helps the trainees to stick to learning material diligently, in addition to the fact that it is more interactive and immersive. In this case, we conceived a gamified 3D multi-user virtual learning environment (3DMUVLE) in the form of a game as a solution. The game was divided into three sections: learning material, quiz, and simulation. Table 3 shows more detailed description regarding these topics. The game starts with the trainees answering questions from the pre-test. Thereafter, they are presented learning material (opened PDF and played videos). Then, they simulate virtually all steps of practical surveys in the virtual environment. Lastly, they undertake a post-test. The whole learning activities are shown in Figure 7.

SUPPORT EVALUATION OF THE PROPOSED FRAMEWORK

Referring to Table 6, based on 19 items proposed by Mora et al. (2015), the initial game design framework (ATMSG) had met 9 items (42.10%) of 19 items totally. To complement it, some items must be added.

For the metrics and analytics item, the authors used HMSAM model (number of items=11, total=57.90%). For the viability item, the authors used existing and desired conditions analysis (number of items=12, total=63.15%). For the risk item, the authors used risk scenarios (number of items=13, total=68.42%). while UI/UX (user interface and user experience) and technologies item, authors used Open Simulator Architecture (number of items=15, total=78.95%). So, our proposed framework had met 78.95% of 19 items.

SUCCESS EVALUATION OF KNOWLEDGE GAIN

This evaluation involved 60 participants (54 Male, 6 Female) who were divided into two groups (3DMUVLE group or first group, and conventional group or second group). Their profiles are summarized on Table 7 and Table 8. They are employees of the Statistic Indonesia (BPS-Government Agency) from various provinces/regencies/cities in Indonesia.

Table 6: Proposed Framework Completeness

No	Item	Initial Framework (ATMSG)	Added Items	Proposed Framework	Accumulative Percentage (%)
1	Objective	V	-	V	5.26
2	Viability	-	V	V	10.53
3	Risk	-	V	V	15.79
4	ROI	-	-	-	15.79
5	Stakeholders	-	V	V	21.05
6	Loop	V	-	V	26.32
7	Endgame	V	-	V	31.58

No	Item	Initial Framework (ATMSG)	Added Items	Proposed Framework	Accumulative Percentage (%)
8	On-boarding	-	-	-	31.58
9	Rules	V	-	V	36.84
10	Metrics	-	V	V	42.11
11	Analytics	-	V	V	47.37
12	Fun	V	-	V	52.63
13	Motivation	V	-	V	57.89
14	Social	-	-	-	57.89
15	Desired Behaviors	V	-	V	63.16
16	Ethics	-	-	-	63.16
17	Narrative	V	-	V	68.42
18	UI/UIX	-	V	V	73.68
19	Technology	-	V	V	78.95

Table 7: Profile of 3DMUVLE Participants (First Group)

Description		Quantity	Percent
Gender	Male	23	76.7
	Female	7	23.3
Frequency in playing a game per day	Seldom or never	23	76.7
	Under 2 hours per day	3	10.0
	Over 2 hours per day	4	13.3
Highest education level	Bachelor	30	100.0

Table 8: Profile of Conventional Participants (Second Group)

Description		Quantity	Percent
Gender	Male	23	76.7
	Female	7	23.3
Highest education level	Bachelor	29	96.7
	Graduate	1	3.3

To compare participants' knowledge gain between two groups, the authors prepared 13 questions in multiple choices about the concept of food crops productivity data collecting survey. The authors conducted the test twice, before training (pre-test), and immediately after training (post-test). Participants answered questions through our 3DMUVLE (first group) and through the website (second group). All answers were recorded and saved in MySQL database. These data collection would be processed by Shapiro-Wilk to determine the normality assumption in which sample distribution data are normally distributed or vice versa (Shapiro & Wilk, 1965). This test was selected since the data sample size is less than 50 (Shapiro & Wilk, 1965).

First group (pre-test and post-test)

For the 3DMUVLE group, the mean of pre-test score is 65.90 (standard deviation, SD = 21.44) and the post-test score is 86.92 (SD = 12.14). Using the Shapiro-Wilk test, the authors concluded that pre-test data were normally distributed ($W=0.955$, $p\text{-value}=0.227>0.05$) and post-test data were not normally distributed ($W=0.854$, $p\text{-value}=0.001<0.05$). Because data were not normally distributed, the authors used the non-parametric test (Wilcoxon Signed Rank) to compare two related samples. Based on the Wilcoxon Signed Rank Test, the authors concluded that the difference between pre-test and post-test scores was significant ($Z = -4.295$, $p\text{-value}=0.000<0.05$).

Second group (pre-test and post-test)

For the conventional method (those who learn from e-books and web), the mean of the pre-test score is 68.46 (SD = 20.34) and the post-test score is 81.28 (SD = 12.56). Using the Shapiro-Wilk Test, the authors conclude that pre-test and post-test scores in the conventional groups did not follow normal distribution assumptions ($W_{pre\text{-}test}$=0.920, $W_{post\text{-}test}$=0.901, p-value<0.05). Because data were not normally distributed, the authors used the non-parametric test (Wilcoxon Signed Rank) to compare two related samples. Based on Wilcoxon Signed Rank Test, authors concluded that difference between pre-test and post-test scores was significant (Z = -3.391, p-value = 0.001 <0.05).

Comparison of the first group and the second group (knowledge gain)

Before conducting 2-independent samples test using the Mann-Whitney U Test, the authors conducted a normality test and homogeneity of variance test as residual assumption test. Based on Shapiro-Wilk, authors concluded that knowledge gain score data did not follow normal distribution assumption (W_{group1}=0.855, p-value=0.001<0.05 and W_{group2}=0.921, p-value = 0.028<0.05). Based on Levene's Test, authors obtained W=0.138 and p-value=0.711>0.05, which means that the variance of two data was homogeneous. Figure 10 and Figure 11 show the differences in knowledge gain between the training using the game and conventional training.

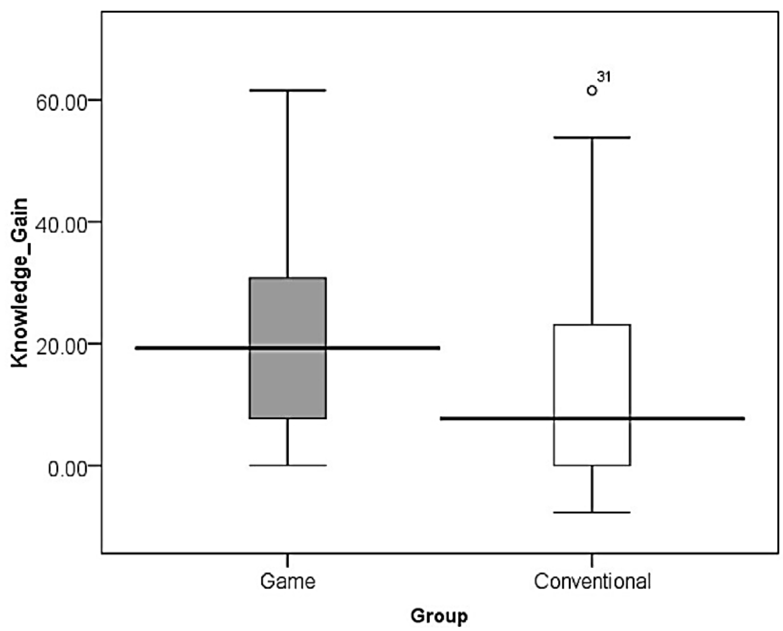


Figure 10: Boxplot of Knowledge Gain

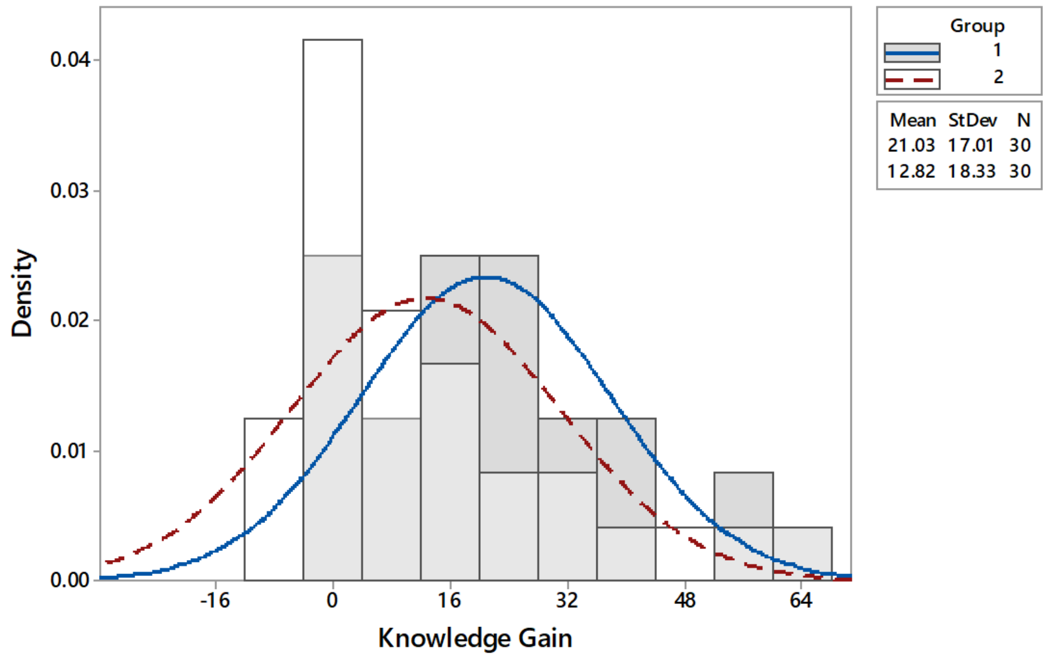


Figure 11: Pattern Similarities of Histogram

As a consequence of this non-homogeneity, the authors use the non-parametric test (U Mann-Whitney / 2-Independent Samples) to test the significance of the difference between knowledge gains of two groups. Based on the test, the result stated that there was a significant difference (Z=-2.153, p-value=0.031<0.05) between the 3D simulation game group (M=21.02, SD=17.01) and conventional group (M=12.82, SD=18.33) in terms of knowledge gain. Table 9 shows the knowledge gain summary.

Table 9: Knowledge Gain Summary

Variable	First Group (n=30)			Second Group (n=30)			Levene's Test Based on Mean (p-value)
	Mean	Standard Deviation	Shapiro-Wilk (p-value)	Mean	Standard Deviation	Shapiro-Wilk (p-value)	
Knowledge Gain	21.02	17.01	0.028*	12.82	18.33	0.001*	0.711**

*p-value<0.05, **p-value>0.05

Application Evaluation

Motivation gain

The authors used validity and reliability tests before comparing two groups in terms of motivation impact. These techniques are used to increase transparency and accuracy of evaluation from collected data (Tavakol & Dennick, 2011): validity known as a test to ensure all the items of collected data is essential and discard undesirable items (Boudreau, Gefen, & Straub, 2001; Lewis, Snyder, & Rainer, 1995) and reliability tests related to measuring the consistency of collected data over a variety of conditions in which the same results should be obtained (Nunnaly & Bernstein, 1994). In this research, the Spearman Correlation Coefficient was chosen to perform the validity test. Cronbach's

Alpha was selected to do a reliability test as the most popular method of testing for internal consistency (Drost, 2011). Based on the validity test, the authors concluded that 10 question items were valid (p-value<0.05, Spearman Correlation Coefficient>0.3610). Based on the reliability test, Cronbach's alpha of two variables was 0.868 and 0.740, those are reliable. Table 10 shows the question item for each variable.

Table 10: Question Item per Variable

No	3D Simulation Game			Conventional		
	Question	Spearman Correlation Coefficient	Cronbach's Alpha	Question	Spearman Correlation Coefficient	Cronbach's Alpha
1	This method gives me engagement and enjoyment	0.824	0.740	This method gives me engagement and enjoyment	0.743	0.868
2	This method gives me curiosity	0.725		This method gives me curiosity	0.541	
3	This method increases my learning focus	0.845		This method increases my learning focus	0.769	
4	This method is easy to use	0.760		This method is easy to use	0.676	
5	This method produces better knowledge	0.900		This method produces better knowledge	0.822	

Furthermore, the authors conduct Wilcoxon signed rank test and the result was that the 3DMUVLE method (M=5.86, SD=0.63) gives better motivation than the conventional method (M=3.55, SD=1.15). This was statistically significant (p-value=0.000<0.05) as shown in Figure 12.

User Acceptance Test (UAT) Model

This research uses the Hedonic-Motivation System Adoption Model (HMSAM) (Lowry, Gaskin, Twyman, Hammer, & Roberts, 2013) to model the UAT. HMSAM analyzes variables that impact user acceptance in using a system or application. This model was developed from Van der Heijden's Model (*Perceived Ease of Use*, *Perceived Usefulness*, and *Enjoyment*) where the use of second-order construct *Joy* was replaced by the construct *Cognitive Absorption* (CA). This replacement was aimed to better represent the intrinsic motivation of users. This second-order construct consisted of four first order constructs, namely *Enjoyment*, *Control*, *Curiosity*, and *Focused Immersion* (intrinsic motivation). The authors modified the model with some questions to align with the research focus. Table 11 shows the HMSAM variable that used to UAT Model.

In our model, the first-order constructs and the second-order constructs are used as variables for 33 questions. Prior to conducting analysis, the authors conducted a validity test and reliability test to all question instruments. Based on the validity test, the authors concluded that all items (33 questions) are valid (Spearman Correlation Coefficients>R-Table (0.3610), p-value<0.001). Furthermore, the results of the reliability test indicated that the seven variables were reliable (Cronbach's alpha>0.6), as shown in Table 12.

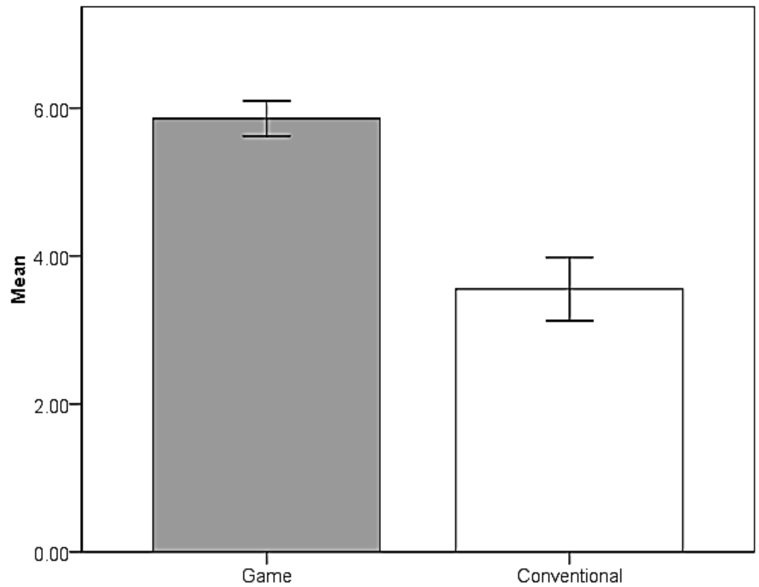


Figure 12: Mean of Motivation Perception. ±SE (CI=95%)

Table 11: HMSAM Variables

No	Variable	Description
1	Control (CTL)	The participants' perception of being in charge of the interaction
2	Curiosity (CUR)	The extent the experience arouses an individual's sensory and cognitive curiosity
3	Heightened enjoyment (JOY)	The pleasurable aspects of the interaction described as being fun and enjoyable rather than boring
4	Focused immersion (FI)	The experience of total engagement where other attention demands are, in essence, ignored
5	Perceived Usefulness (PU)	The condition when the user believes that using technology will increase their performance
6	Perceived Ease of Use (PEOU)	The condition when participants believe in using a system, they don't need a big effort
7	Behavioral Intention to Use (BIU)	Users' intention to use a system or application

Table 12: Validity and Reliability Test Summary

Variable	Question Items	Correlation Analysis			Cronbach's Alpha
		Spearman Correlation Coefficient	p-value	Conclusion	
Heightened Enjoyment (JOY)	JOY1	0.796	0.0000*	Valid	0.846
	JOY2	0.828	0.0000*	Valid	
	JOY3	0.759	0.0000*	Valid	
	JOY4	0.653	0.0000*	Valid	
	JOY5	0.870	0.0000*	Valid	
Control (CTL)	CTL1	0.596	0.0005*	Valid	0.628
	CTL2	0.765	0.0000*	Valid	
	CTL3	0.612	0.0003*	Valid	
	CTL4	0.755	0.0000*	Valid	
	CTL5	0.648	0.0001*	Valid	
Focused Immersion (FI)	FI1	0.621	0.0002*	Valid	0.818
	FI2	0.788	0.0000*	Valid	
	FI3	0.787	0.0000*	Valid	
	FI4	0.810	0.0000*	Valid	
	FI5	0.698	0.0000*	Valid	
Curiosity (CUR)	CUR1	0.947	0.0000*	Valid	0.896
	CUR2	0.907	0.0000*	Valid	
	CUR3	0.848	0.0000*	Valid	
Perceived Ease of Use (PEOU)	PEOU1	0.805	0.0000*	Valid	0.935
	PEOU2	0.797	0.0000*	Valid	
	PEOU3	0.876	0.0000*	Valid	
	PEOU4	0.822	0.0000*	Valid	
	PEOU5	0.862	0.0000*	Valid	
	PEOU6	0.864	0.0000*	Valid	
Perceived Usefulness (PU)	PU1	0.707	0.0000*	Valid	0.821
	PU2	0.773	0.0000*	Valid	
	PU3	0.624	0.0002*	Valid	
	PU4	0.817	0.0000*	Valid	
	PU5	0.748	0.0000*	Valid	
	PU6	0.763	0.0000*	Valid	
Behavioral Intention to Use (BIU)	BIU1	0.966	0.0000*	Valid	0.855
	BIU2	0.688	0.0000*	Valid	
	BIU3	0.966	0.0000*	Valid	

*p-value<0.001

Using descriptive analysis, the authors obtained the criteria of variables based on participants' assessment, as shown in Table 13.

In Table 13, the authors concluded that two variables showed high criteria, which are perceived ease of use (PEOU) and perceived usefulness (PU). Meanwhile, five variables exhibited medium criteria, which are JOY, CTL, FI, CUR, and BIU. Then, the authors depicted the HMSAM that represents the relationship between all seven variables, as shown in Figure 13.

Table 13: Descriptive Analysis per Variables

No	Variable	Theoretical Range	Range	Mean	Standard Deviation	Value	Criteria
1	Heightened Enjoyment	5-25	13-18	20.00	3.49	0.80	Medium
2	Control	5-25	13-18	20.00	2.72	0.80	Medium
3	Focused Immersion	5-25	13-18	17.50	3.47	0.70	Medium
4	Curiosity	3-15	8-12	12.47	2.28	0.83	Medium
5	Perceived Ease of Use	6-30	23-30	24.63	4.16	0.82	High
6	Perceived Usefulness	6-30	23-30	23.73	3.96	0.79	High
7	Behavioral Intention to Use	3-15	8-12	12..20	1.99	0.81	Medium

Based on the model, and thus our hypotheses: (1) PU, PEOU, FI, CUR, CTL, JOY have positive impact on BIU. (2) PEOU, CUR have positive impact on FI; (3) PEOU has positive impact on PU; (4) PEOU has positive impact on CUR; (5) PEOU has positive impact on CTL; (6) PEOU has positive impact on JOY.

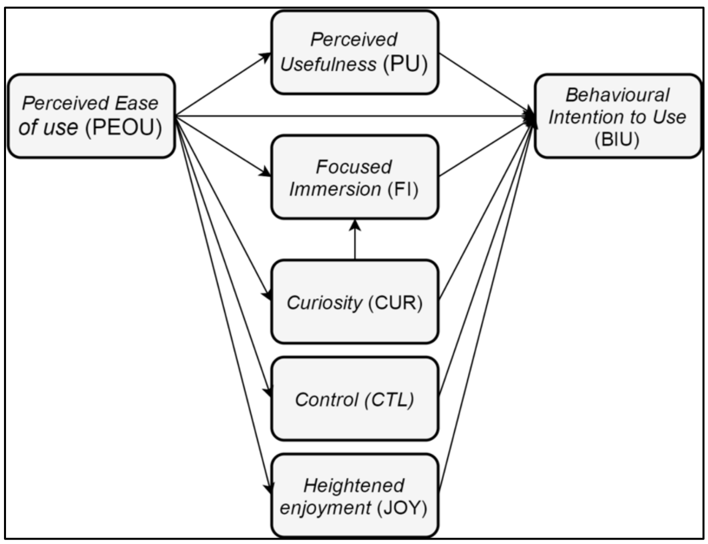


Figure 13: Hedonic-Motivation System Adoption Model (HMSAM)

In this model, the value of a response sub-model (dependent variable) from a collection of independent variables was expected. The multiple linear regression method was selected due to a considerably small sample size of 30. In addition, one linear regression model could not describe the model overall. So, the authors used six separate sub regression analysis models to test the model in full. This analysis was conducted by normality test, autocorrelation test, and Method of Successive Internal (MSI). The Kolmogorov-Smirnov's normality test was used to determine whether data were normally distributed (Chakravarti, Laha, & Roy, 1967). The autocorrelation test was handled using Durbin-Watson's (DW) method based on the simple observation that if residuals are autocorrelated then neighboring residuals should tend to be more similar in value than arbitrary pairs of residuals (Durbin & Watson, 1950). The MSI was performed to transform ordinal data to interval data for regression test.

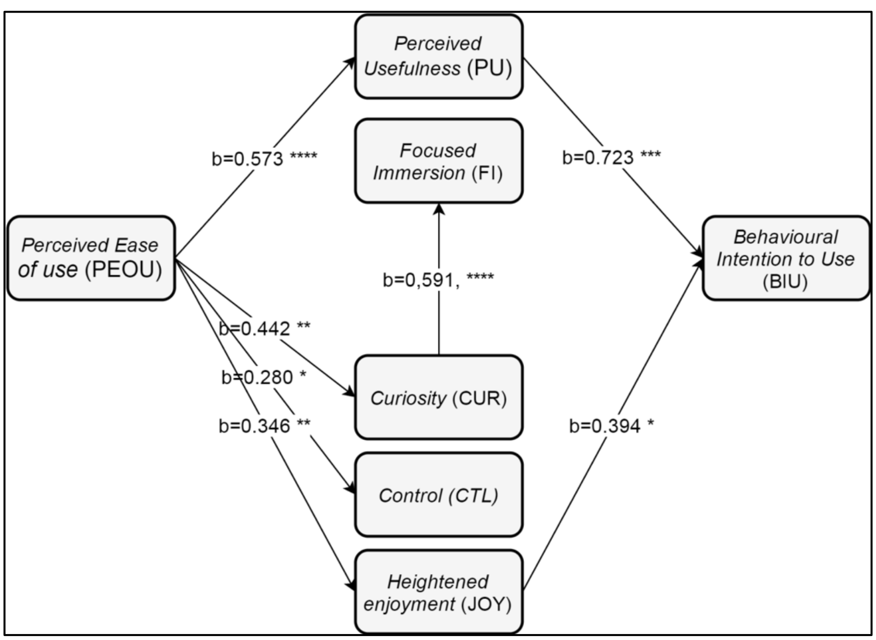
Table 14: Linear Regression Analysis Summaries

No	Dependent Variable (Y)	Independent Variable (X)	Simultaneous F-Test (p-value)	Partial t-Test (p-value)	Regression Coefficient	Normality Test Kolmogorov-Smirnov (p-value)	Autocorrelation Test (DW)
1	BIU	JOY	0.000****	0.086*	0.394	0.901	1.955
		CTL		0.111	-0.320		
		FI		0.281	-0.254		
		CUR		0.327	0.210		
		PEOU		0.838	-0.034		
		PU		0.004***	0.723		
2	FI	PEOU	0.000****	0.313	0.132	0.643	1.751
		CUR		0.000****	0.591		
3	PU	PEOU	0.000****	0.000****	0.573	1.000	-
4	CUR	PEOU	0.022**	0.022**	0.442	0.509	-
5	CTL	PEOU	0.055*	0.055*	0.280	0.940	-
6	JOY	PEOU	0.046**	0.046**	0.346	0.477	-

*p-value<0.1, **p-value<0.05, ***p-value<0.01, ****p-value<0.001

There were several statistical tests that the authors conducted in this evaluation, including normality test, autocorrelation test, simultaneous F-test, and partial T-test. The autocorrelation test was especially used for multiple linear regression models to ensure there was no correlation between the independent variables in a model, while F-test and T-test were used to test the significance of independent variables in the model. All test results were summarized in Table 14.

At the specific confidence interval (CI), the authors could determine which variables that strongly influenced BIU. Based on linear regression analysis, authors concluded that Perceived Usefulness (PU) variable (b = 0.723, p-value<0.01) was the strongest predictor to BIU, followed by Enjoyment variable (b=0.394, p-value<0.1). It means that the participants' tendency to use the 3DMUVLE was most affected by PU and JOY variables. Figure 14 shows the final model of the analysis.



*p-value<0.1, **p-value<0.05, ***p-value<0.01, ****p-value<0.001

Figure 14: Final Model (Significant Paths Only)

In other sub models authors concluded that: (1). PEOU (b = 0.573, p-value <0.001) has positive effect on PU; (2) PEOU (b = 0.346, p-value <0.05) has positive effect on JOY; (3) PEOU (b = 0.28, p-value <0.1) has positive effect on CTL; (4) PEOU (b = 0.442, p-value <0.05) has positive effect to CUR; (5) CUR (b=0.591, p-value<0.001) has positive effect to FI. These mean that the ease of use of the 3DMUVLE method could increase participants' usefulness, enjoyment, control, and curiosity aspects.

Conclusion and Future Works

Conclusion

Based on the foregoing analysis, four concluding points can be drawn: (1) in increasing knowledge, the authors proposed a 3DMUVLE for online training of food crops productivity collecting data survey; (2) based on an experimental study, the authors concluded that 3D simulation game produced better knowledge gain; (3) a 3D simulation game was more able to increase enjoyment, curiosity, focused immersion, and usefulness aspects and these will produce better knowledge gain; (4) enjoyment and perceived usefulness were strongest variables that influenced behavioral intention to use.

It turns out that the last concluding point also answers the research question, that is, the strongest variables in predicting the behavioral intention to use were enjoyment and perceived usefulness.

In addition to bringing up many advantages, e-learning introduces also some disadvantages. Hara and Kling (2001) state that e-learning has disadvantages such as making users frustrated, anxious, confused, and less interested in following the lesson. In this paper, we proposed to alleviate such disadvantages. This project indicated that the 3DMUVLE can make its trainees enjoy using it and are eager to learn.

Future Works

The 3DMUVLE method developed in this paper is not limited to one training only. Rather, it could be adapted to other domains of knowledge and skills. Authors also suggest improving some features in the game, such as quality of instruction in the simulation or use of social and humor aspects. These may increase learning focus and engagement so that in turn they will increase users' knowledge gain.

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