Kinetik: Game Technology, Information System, Computer Network, Computing, Electronics, and Control
Journal homepage: http://kinetik.umm.ac.id
ISSN: 2503-2267
Vol. 6, No. 1, February 2021, Pp. 27-40

Balancing entertainment, cost, and educational strength: a design framework for medium-coupling educational games

Pratama Wirya Atmaja*[1], Sugiarto[2]
Department of Informatics, University of Pembangunan Nasional "Veteran" Jawa Timur, Indonesia[1,2]

Article Info
Keywords:
Educational Games, Design Framework, Medium Coupling, Role-Playing Games

Article history:
Received: November 25, 2020
Accepted: January 5, 2021
Published: February 28, 2021

Cite:
Atmaja, P. W., & Sugiarto. (2021). Balancing Entertainment, Cost, and Educational Strength: A Design Framework for Medium-Coupling Educational Games. Kinetik: Game Technology, Information System, Computer Network, Computing, Electronics, and Control, 6(1).
https://doi.org/10.22219/kinetik.v6i1.1158

*Corresponding author.
Pratama Wirya Atmaja
E-mail address:
pratama_wirya.fik@upnjatim.ac.id

Abstract
Games are powerful tools for teaching and learning, especially in the age of Education 4.0. The rapid growth of educational games is hindered by various problems, including their development cost. The medium coupling approach, which allows an educational game to be both engaging and economical, is one potential solution to the problem; unfortunately, it has received only sporadic attention. This study aims to explore the matter of designing medium-coupling educational games through a design framework. The framework dissects an educational game's game content and educational content into parts to be interconnected. We applied the framework to design and develop an educational role-playing game (RPG). Sixty first-year Informatics students tested the game, which presented three learning topics with different characteristics. A post-test questionnaire's results validate the game's entertainment and educational values while also uncovering how it works under different learning contents. A discussion with the participants gathered insightful suggestions and critiques, which, together with the questionnaire's results, are synthesized into design principles for medium-coupling games. We conclude that the framework is useful for creating games that are entertaining, educational, and cost-efficient.

1. Introduction

Serious games are a term that has been rapidly gaining prominence [1] and grown to an impressive level [2]. It is defined as games that use their entertainment factor to achieve non-entertainment goals [3]. An essential subset of serious games is educational games (also known as game-based learning), which are those that are intended to achieve wide-ranging educational goals [4][5]. Their many benefits are well-studied and documented [6][7].

Despite educational games' strengths, many educational institutions still find their development cost prohibitive [8][6]. Research works on exploring methods and approaches to minimize the cost are, therefore, essential. One such approach is what we term "medium coupling," which allows an educational game to be both engaging and repurposable [9]. The advantage of the approach is immediately apparent; however, it has received only a little attention.

This study aims to delve into the medium-coupling approach by exploring its general design framework. To do so, we first conducted a literature review on several topics related to medium-coupling educational games. Based on the review, we then proposed a design framework for such games. We validated the framework by implementing it to develop an educational game of a specific genre: the role-playing game (RPG). We then tested the game to validate its effectiveness and propose principles for the framework's use.

1.1 Literature Review

The term "educational games" itself has multiple interpretations; therefore, we will pinpoint which interpretation we follow in this study. A game may start as one purely for entertainment but is later repurposed to deliver lessons, i.e., a *commercial off-the-shelf game* [3], or be developed intentionally for education. Such an intentionally-developed educational game can have either bare-bones game mechanics, i.e., a *drill-and-practice game* [10], or more complex ones resembling those in games for entertainment. The latter is the focus of this study.

Generally, every educational game consists of *game content*, e.g., game mechanics and interfaces, and *learning content*, e.g., lessons and assessments [11]. The interplay between the two contents is crucial to the game's success. The consensus in the literature favors the contents being *intrinsically-integrated*, i.e., inseparable and function as one. The intrinsic integration (also known as "tight coupling") ensures that the learning content is integrated "deeply" into the game content; for example, a math game where the enemies' behaviors and weaknesses are based on arithmetic rules. Contrasting the intrinsic integration is the *extrinsic* one (also known as "loose coupling"), which attaches learning content to game content only superficially. An example of an extrinsically-integrated game is one with its gameplay occasionally interrupted by multiple-choice quizzes.

Most researchers agree that intrinsic integration is the ideal one, as it can maximize the educational strength of the game [12][11][13]. However, extrinsic integration can be much less costly and simpler to implement [14]. Undoubtedly, tacking quizzes on to a game is much more straightforward than adjusting the game's inner workings to embody the learning content. Indeed, the integration process's complexity often becomes a bottleneck in educational game development [9].

Besides the intrinsic and extrinsic ones, the literature of educational games recognizes the third content integration approach. If we interpret the content integration as a "spectrum," then the third approach resides between the intrinsic and the extrinsic ones. The approach is rarely mentioned explicitly in the literature, yet we hereafter termed it "medium coupling." It has appeared in the works of Rosyid et al. [9], Garneli et al. [15], Beserra et al. [16], and Atmaja et al. [17]. *Toon Math*[i] is an example of a commercial product utilizing the medium coupling approach.

Simply put, the approach integrates some parts of the game content with some parts of the learning content. Atmaja et al. [17] experimented with a platformer game where the player would defeat enemies and collect items. Performing the two actions allowed the player to gather elements, e.g., binary numbers, to answer a question, e.g., a binary addition. A similar integration manner is found in Rosyid et al. [9], where the player of a dungeon crawling game composed chemical molecules by collecting items representing chemical elements. Unlike in an intrinsically-integrated game, the learning content is not connected to the game's core mechanics; consequently, the content can be replaced without radically modifying the game. Unlike in an extrinsically-integrated game, the learning content is a part of and does not interrupt the gameplay. The two characteristics allow a medium-coupling game to be a feasible compromise: economical to its developer and entertaining and educational to its players.

Unfortunately, cost issues are not the only things standing between a game developer and an educational game of acceptable quality. Game design is an intricate matter, and design frameworks are essential in game development [18]. However, there is a lack of practical design frameworks in the educational game field. We found a lack of studies on systematically designing intrinsically-integrated educational games [19], and the existing studies on the matter have also been fragmentary and inconclusive [20]. General design frameworks for educational games, e.g., the ones by Shi and Shih [21], Arnab et al. [22], and Carvalho et al. [23], tend to provide basic guidelines but do not delve into technical details. It is unfortunate, as even small changes to the game's gameplay elements may dramatically alter player experience [24][25]. Many studies on designing educational games' gameplay elements either (a) cover only specific game types [26][27], or (b) focus on general and reusable elements, e.g., badges and learderboards [28], that, unfortunately, may be deemed superficial [29]. In light of this design-related research gap, we conducted this study.

1.2 Contributions

This study presents two contributions. First, it proposes a design framework for medium-coupling educational games. The framework describes the technicalities of designing such a game of any genre and purpose. Second, this study validates the framework by employing it to develop a medium-coupling game of a specific genre. Through the game's testing process, this study uncovers several considerations for the framework's use. The framework's validation provides qualitative and quantitative insights into the entertainment and educational aspects of medium-coupling games. The third aspect, development cost, is also discussed and validated, albeit only preliminarily and qualitatively.

2. Method

We will explain our design framework for medium-coupling educational games and how we validated the framework. We conducted the validation by implementing the framework to design and develop an RPG. We then tested the game under a mixed-method approach, which collected quantitative data through a questionnaire and qualitative data through a discussion with the players.

2.1 Proposed Design Framework for Medium-Coupling Educational Games

Figure 1 shows our proposal for the design framework. Under the framework, a medium-coupling educational game consists of four game content components, three learning content components, and several connections between the components. Learning content may contain one or more learning topics, e.g., chemistry. Following the standard practices of medium-coupling games in the literature (as discussed in the literature review), our framework split each learning topic into two parts, the first being learning elements, which are the building blocks of knowledge in the topic. For example, chemistry may have chemical element symbols as its learning elements. The second part of a learning topic is lessons, each consisting of a rule and a description. A rule dictates a meaningful arrangement of learning elements; e.g., the chemistry topic may have rules on chemical molecules such as sulfuric acid. A description serves as a way to communicate the corresponding rule to the player.

Game content consists of four core elements of a game: game mechanics, objects, states, and interfaces [30][31][32]. In the framework, game objects serve as a bridge between game content and learning content. Before or during a game session, each game object is assigned to a specific learning element. As seen in Figure 1, the player must follow a particular flow to influence the learning content indirectly. In Figure 1, the flow consists of red arrows

starting from mechanics to game states. First, the player executes one or several game mechanics (e.g., shooting and jumping) to manipulate game objects (e.g., enemies). The game object manipulation will arrange (e.g., linearly) the learning elements associated with the objects, and the arrangement is then checked according to available rules. If the arrangement meets a specific rule, game states related to the player's learning process, e.g., score, will be updated.

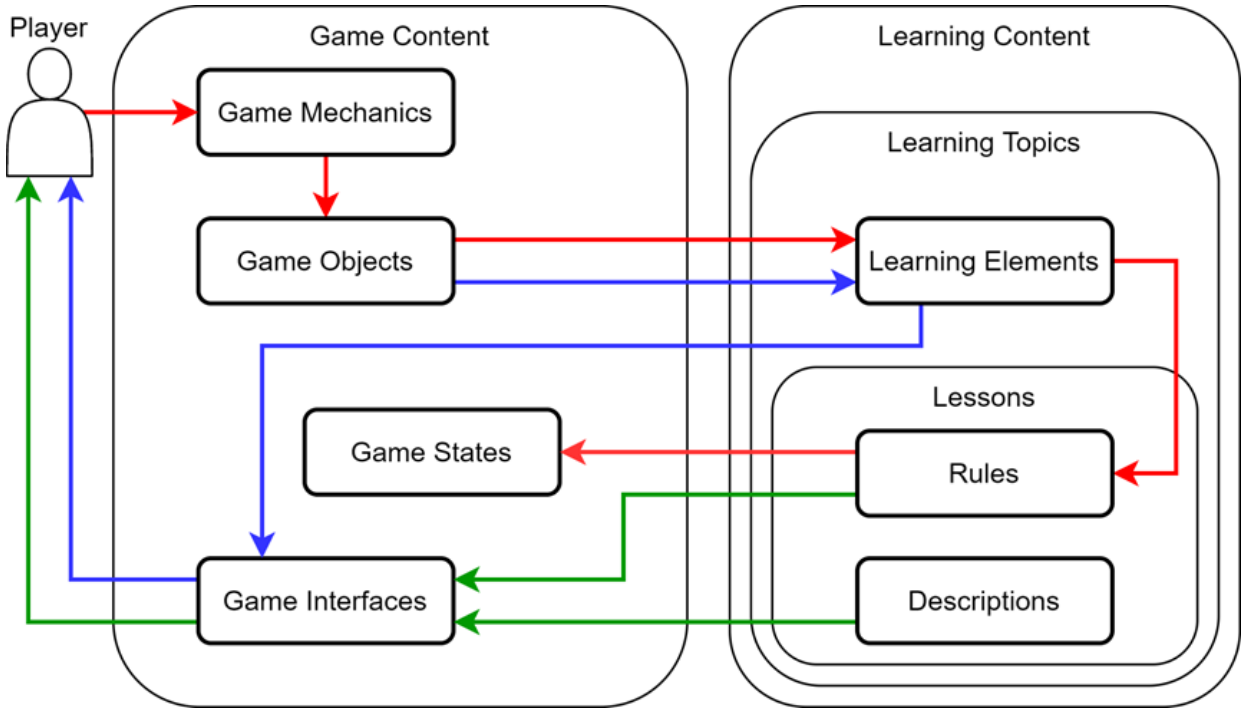


Figure 1. The Proposed Design Framework for Medium-Coupling Educational Games

Game interfaces inform the player of several things, two of which are rules and descriptions of lessons. The green arrows represent the flow in Figure 1. The information can be in any form (e.g., text or animations) and manner (explicit or implicit). The interfaces can also accept the third information flow, consisting of the blue arrows, about which learning element is assigned to which object.

Cost-wise, a game developed under the framework is most efficient in facilitating different yet similar learning contents. In such cases, new learning content requires changes to only *cross-content* connections between several components: (1) between objects and learning elements, (2) between learning elements and interfaces, (3) between game states and lesson rules, (4) between interfaces and the rules, and (5) between interfaces and lesson descriptions. Each cross-content connection is non-intrusive to the connected components; for example, to make specific game objects represent specific learning elements, the developer can add one variable to the objects for the elements' identifiers. Likewise, the developer can also utilize game state variables that record which lesson rules the player has fulfilled, which the game can then read to conduct gameplay changes. Such lightweight connections allow each connected component to be modified or replaced without significantly affecting its pair in the connection, thus keeping the content replacement cost low.

However, the game's cost efficiency will be lower when the new learning content is drastically different from the old one. For example, learning topics with rules that arrange the elements as *graphs* (e.g., molecular structures) will require more complex interaction than topics with linearly-ordered elements (e.g., English grammar). Consequently, the developer may have to modify the *game mechanics* to facilitate the new interaction, e.g., adding new player actions to deal with branchings in the graphs. Likewise, changes to *game interfaces* may also be necessary, e.g., if the new lesson rules are more complicated and thus require a different approach to explain on the screen. In general, adapting the game to significantly different learning contents is a vast topic and merits extensive studies in the future.

It should also be noted that our framework only includes the *minimal* connections required by a medium-coupling game. An example of a useful but optional connection is between game objects and game states, which allows the player to collect and store objects in their *inventory* [33], which is itself a type of "game state." That way, the player can have greater control in managing game objects and the associated learning elements. Another useful connection is between game objects and lesson rules and descriptions, which allow specific objects (e.g., non-player characters or NPCs) to inform the player about the learning content.

2.2 Design of the Role-Playing Game

Figure 2 shows the design of the game content and learning content in our RPG. We based the design on the design framework with several adjustments to suit an RPG. Each game session in the RPG presented one learning topic, which the player would select before starting the session.

According to [34], an RPG presents an overarching mission or *campaign* composed of in-game tasks or *quests*. The campaign and quests are presented through a storyline. A quest is initiated, carried on, and completed through interacting with game objects such as NPCs. In our RPG, the player role-played as a hero tasked with liberating a village from evil. From the start of the game, the player could directly confront the king of evil monsters. However, defeating the king would be impossible without the help of three special items. Acquiring the items constituted the game's quests, which were done through interacting with villagers, exploring the wilderness, combating monsters, and collecting ingredients for the items.

The RPG employed three mechanics for combat, item collection, and dialog to support the integration between its learning content and game content. The player's inventory [33] represented the game states in Figure 1. In the RPG, learning elements were assigned to specific pickable items named "energy pieces." The player could pick an energy piece and move it into their inventory through the collecting mechanic. The collection flow follows the solid red arrows in Figure 2. However, the player could not merely find the energy pieces in the game world; they had to fight and defeat regular enemies so that they dropped the items on the ground. Dealing with the enemies was done through the real-time combat mechanic, whose flow is represented by solid blue arrows in Figure 2. The dropped energy pieces would possess random learning elements, and the player must correctly assess which pieces to pick to satisfy a lesson rule.

The dialog mechanic was needed to put the collected energy pieces into use. Through the mechanic, the player could converse with three elders of the village. Each elder would inspect the player's inventory for energy pieces. If the pieces' learning elements were arranged according to a rule, the elder would bestow, i.e., put into the inventory, one special item to the player. This flow follows the solid orange arrows in Figure 2. Effectively, the player dealt with three lessons in each game session.

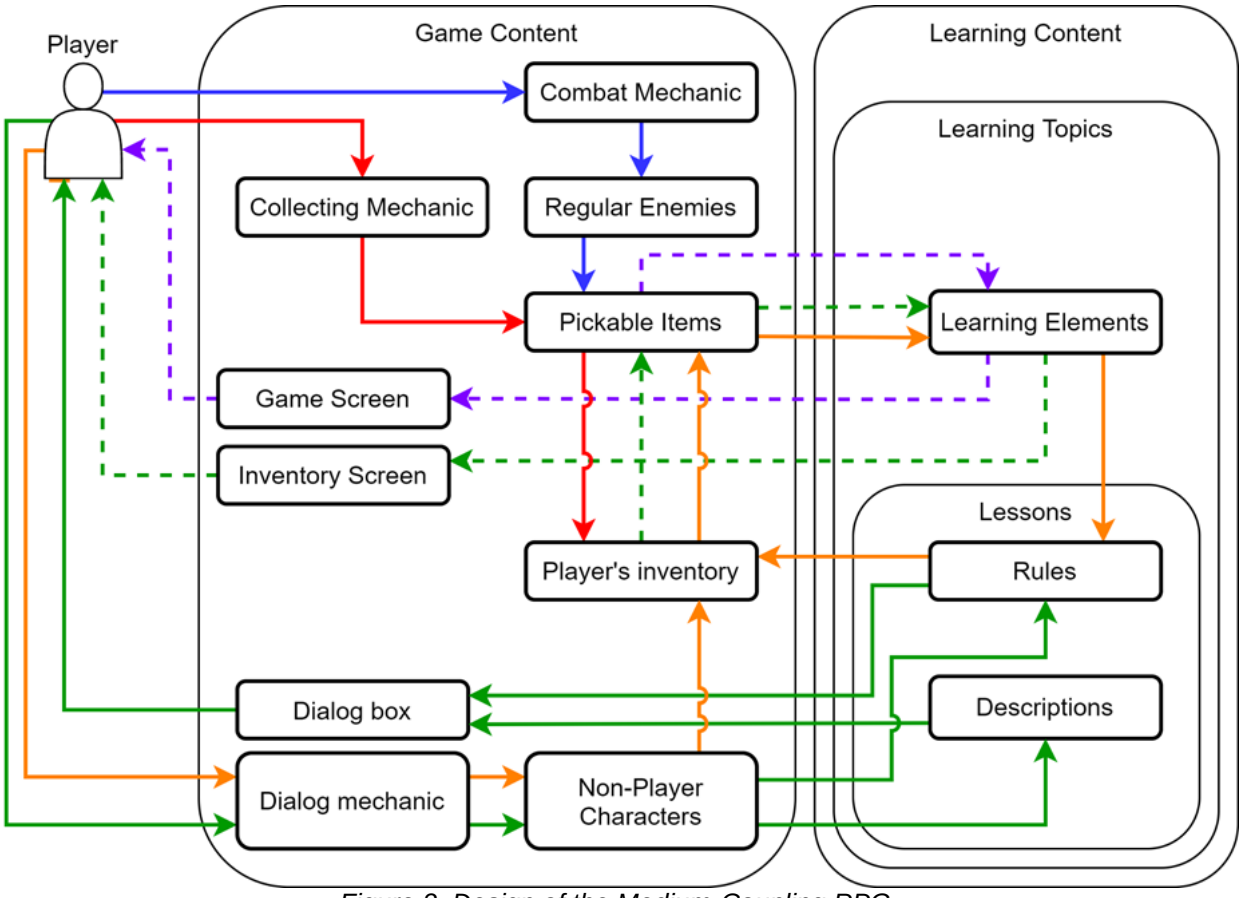


Figure 2. Design of the Medium-Coupling RPG

Of the three mechanics, the combat and collecting ones represented the player's core tasks, as they required skills and provided challenges to the player. On the other hand, the dialog mechanic merely served as a narrative tool

and a mechanism for checking learning element arrangements. Therefore, the combat and collecting mechanics formed our RPG's *game loops*, which were atomic units of the player's gameplay experience [35]. The game loops determined the RPG's fun factor; mastering the loops was the player's main incentive to keep playing. As we did not intend the game to be played for long, we designed the combat and item collection to be simple. Weapon choices were limited, enemies were somewhat predictable, and energy pieces' arrangements were linear and straightforward, as explained in the "learning content specification" subsection.

The main game screen, the inventory screen, and dialog boxes represented the game interfaces in our design. When the mouse cursor pointed at an energy piece on the ground, the learning element associated with the piece would be displayed on the game screen. If the player had energy pieces in their inventory, they could check the pieces' learning elements on the inventory screen. The two flows of information follow the dashed purple and dashed green arrows in Figure 2. As shown with the solid green arrows, the player could also read a lesson's rule and description on the dialog box during conversing with a village elder.

Several cross-content connections between components in Figure 2 were required in the RPG. Like the ones in Figure 1, the connections were also lightweight and allowed flexible component replacements. We will discuss one connection example, which is between village elders (NPCs) and lesson descriptions. Figure 3 shows a more detailed connection between the elders and lesson descriptions. In the RPG, we used an event system for the NPCs' behaviors. Each NPC had a set of events, which the player could activate by interacting with the NPC through the dialog mechanic. Connecting the NPC to a specific lesson description was done through a dialog event connected to the description. Changing which description to show would be done by merely changing the lesson's identifier in the event.

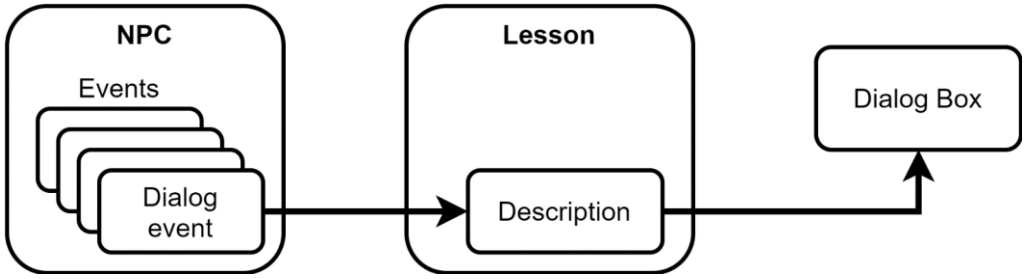


Figure 3. The Connection between an NPC and a Lesson Description

2.3 Flow and Participants of the Testing Process

Figure 4 shows the flow of our testing process, which was entirely online. Sixty first-year students of the Informatics Department of the University of Pembangunan Nasional "Veteran" Jawa Timur (UPNVJT) participated in the process. We split the participants randomly into three groups, and each group received and played a version of the game. Every version of the game presented three selectable learning topics, with each topic having a different set of lessons for each game version. We intended the grouping and the game versions to prevent cooperation between the participants. For that reason, we did not inform the participants of the matter.

We required every participant to try to finish the game under all three topics. Due to bugs, however, some participants were only able to finish one or two topics. Regardless of technical problems, all participants filled the questionnaires and participated in the discussion.

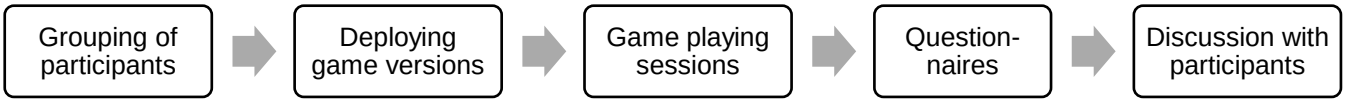


Figure 4. The Flow of the Testing Process

2.4 Questionnaire Design

We employed a two-part questionnaire for the learning content and the game content. The first part measured each participant's experience and satisfaction with the game. Table 1 shows the part, which was based on the GUESS scale [36]. The second part, shown in Table 2, measured the quality of each participant's learning experience. The part was based on the robust EGameFlow model [37], and each participant filled it once for each learning topic. As the testing process involved Indonesian students, we translated GUESS and EGameFlow into Bahasa Indonesia. Each item of our questionnaire was rated on a seven-point Likert scale.

For each factor of the two parts, we calculated the aggregated mean and standard deviation values. We also calculated the Cronbach's alphas of the factors to measure their reliability. Due to our questionnaire's items not being in their original wordings and language, the reliability measurement became especially important. Ideally, the factors should have high means, low standard deviations, and high Cronbach's alphas.

Table 1. The GUESS-based Questionnaire Items

Factor	No.	Original Item	Item in Bahasa Indonesia
Usability/ Playability	1	I think it is easy to learn how to play the game.	*Mempelajari cara memainkan gimnya adalah mudah.*
	2	I find the controls of the game to be straightforward.	*Skema kontrol gimnya tidak berbelit-belit.*
	3	I always know how to achieve my goals/objectives in the game.	*Sewaktu bermain, saya selalu tahu cara mencapai tujuan-tujuan permainannya.*
	4	I find the game's interface to be easy to navigate.	*Antarmuka gimnya mudah digunakan.*
	5	I do not need to go through a lengthy tutorial or read a manual to play the game.	*Saya dapat langsung memainkan gimnya tanpa harus membaca manual mendetail.*
	6	I think the information provided in the game (e.g., onscreen messages, help) is clear.	*Informasi-informasi di dalam jalan permainan gimnya dapat dipahami dengan jelas.*
Play Engross-ment	7	I feel detached from the outside world while playing the game.	*Gimnya asyik dimainkan hingga membuat saya melupakan hal-hal di sekitar saya.*
	8	I cannot tell that I am getting tired while playing the game.	*Saya tidak merasa capek sewaktu memainkan gimnya.*
	9	I tend to spend more time playing the game than I have planned.	*Tanpa sadar, saya memainkan gimnya lebih lama dari rencana saya.*
	10	Whenever I stopped playing the game I cannot wait to start playing it again.	*Setelah saya selesai memainkan gimnya, saya merasa ingin memainkannya lagi.*
Creative Freedom	11	I feel the game allows me to be imaginative.	*Saya merasa gimnya membebaskan dan tidak mengekang imajinasi saya.*
	12	I feel the game allows me to express myself.	*Saya merasa dapat mengekspresikan diri saya sewaktu memainkan gimnya.*
	13	I feel I can explore things in the game.	*Saya merasa dapat bebas mengeksplorasi berbagai hal di gimnya.*
Narrative	14	I feel my curiosity is stimulated as the result of playing the game.	*Gimnya dapat memancing rasa penasaran saya.*
	15	I think the characters in the game are well developed.	*Saya merasa tokoh-tokoh gimnya ditulis dengan baik.*
	16	I am captivated by the game's story from the beginning.	*Saya terpukau dengan jalan cerita gimnya sejak bagian awalnya.*
	17	I enjoy the fantasy or story provided by the game.	*Saya menikmati unsur fantasi di gimnya.*
	18	I can identify with the characters in the game.	*Saya merasa dapat bersimpati dengan tokoh-tokoh ceritanya.*
	19	I am emotionally moved by the events in the game.	*Saya merasa tergerak secara emosional oleh peristiwa-peristiwa di ceritanya.*
	20	I am very interested in seeing how the events in the game will progress.	*Saya tertarik mengikuti perkembangan ceritanya.*
	21	I can clearly understand the game's story.	*Saya dapat memahami jalan ceritanya dengan baik.*

2.5 Learning Content Specification

We employed three informatics-related learning topics: propositional logic, software development, and algorithms. As explained before, each topic was represented by three lessons in a game session. Table 3 shows the specification of the learning topics and their lessons.

The propositional logic topic was about composing formal logic statements of specific laws, e.g., De Morgan's. Each learning element of the topic was a formal logic symbol, e.g., conjunction and disjunction symbols. On the other hand, the software development topic taught the steps, e.g., "implementation," in a development methodology, e.g., the Waterfall. Meanwhile, the algorithm topic was about composing an algorithm's pseudocode, e.g., the Bubble Sort. Consequently, the topic's learning elements consisted of pseudocode lines, e.g., "if x < y." Each topic had simple rules that dictated linear orderings of learning elements.

The topics had different characteristics, which let us observe how the game worked under different learning contents. The participants were most familiar with propositional logic, which is already taught in high school and the first year in Informatics UPNVJT. On the other hand, software development and algorithms likely presented wholly new

experiences to the participants. Furthermore, the learning elements of algorithms might look cryptic to most, if not all, of the participants. It is in contrast with the regular verbs that made up software development's learning elements. The algorithm topic also had the most number of answer elements, which was 29. It was due to each answer element representing one line in an algorithm's pseudocode, thus preventing the element from being reusable in most cases. The high number of unique answer elements likely made it harder for the participants to memorize the elements.

Table 2. The EGameFlow-based Questionnaire Items

Factor	No.	Original Item	Item in Bahasa Indonesia
Knowledge Improve-ment	1	The game increases my knowledge.	*Jalan permainan gimnya menambah pengetahuan saya seputar* [topic].
	2	I catch the basic ideas of the knowledge taught.	*Jalan permainan gimnya membuat saya memahami, secara garis besar, tentang* [topic].
	3	I try to apply the knowledge in the game.	*Saya selalu mencoba memahami dan mengerjakan materi* [topic]*-nya dengan maksimal.*
	4	The game motivates the player to integrate the knowledge taught.	*Saya termotivasi untuk menerapkan pengetahuan* [topic] *yang saya dapatkan di kehidupan nyata.*
	5	I want to know more about the knowledge taught.	*Saya merasa ingin mengetahui lebih jauh mengenai* [topic].
Challenge	6	The difficulty of challenges increase as my skills improved.	*Tingkat kesulitan materi* [topic]*-nya meningkat mengiringi peningkatan pemahaman saya.*
	7	The game provides new challenges with an appropriate pacing.	*Meningkatnya tingkat kesulitan materi* [topic]*-nya cukup sesuai, tidak terlalu cepat maupun lambat.*
	8	The game provides different levels of challenges that tailor to different players.	*Tingkat kesulitan setiap materi* [topic]*-nya sesuai untuk saya.*
Autonomy	9	I feel a sense of control over the game.	*Saya merasa dapat mengontrol pembelajaran* [topic]*-nya agar sesuai keinginan atau kebutuhan saya.*

Table 3. The Specification of the Learning Topics

Topic	Lesson number	Element number	Element per lesson (mean)	Participant's familiarity
Propositional logic	6	9	6.33	Yes
Software development	4	9	5.75	No
Algorithms	5	29	6.40	No

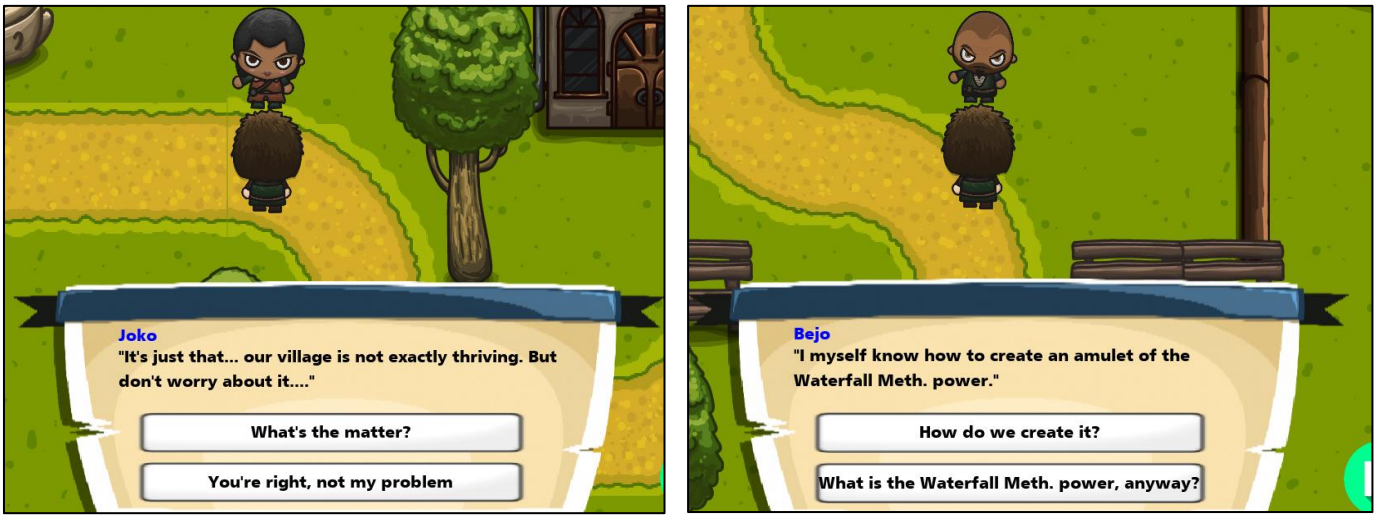
3 Results and Discussions

3.1 The Medium-Coupling Role-Playing Game

Figure 5 and Figure 6 show screenshots of our RPG, which was developed with GameMaker Studio 2. We have translated the game into English for this paper. Figure 5 shows two dialogs with two essential NPCs. The village chief initializes the campaign by explaining the village's problem briefly. The elder in Figure 5b explains a lesson on the Waterfall methodology, which belongs to the software development topic. Following the medium coupling approach, the dialog partially integrates the lesson into the narrative. The lesson's name ("Waterfall Methodology") is mentioned in the dialog as one necessary part for defeating the monster king. On the other hand, the lesson's description is told as-is, i.e., not integrated into the narrative. That way, the Waterfall methodology can be replaced with other lessons without disrupting the narrative.

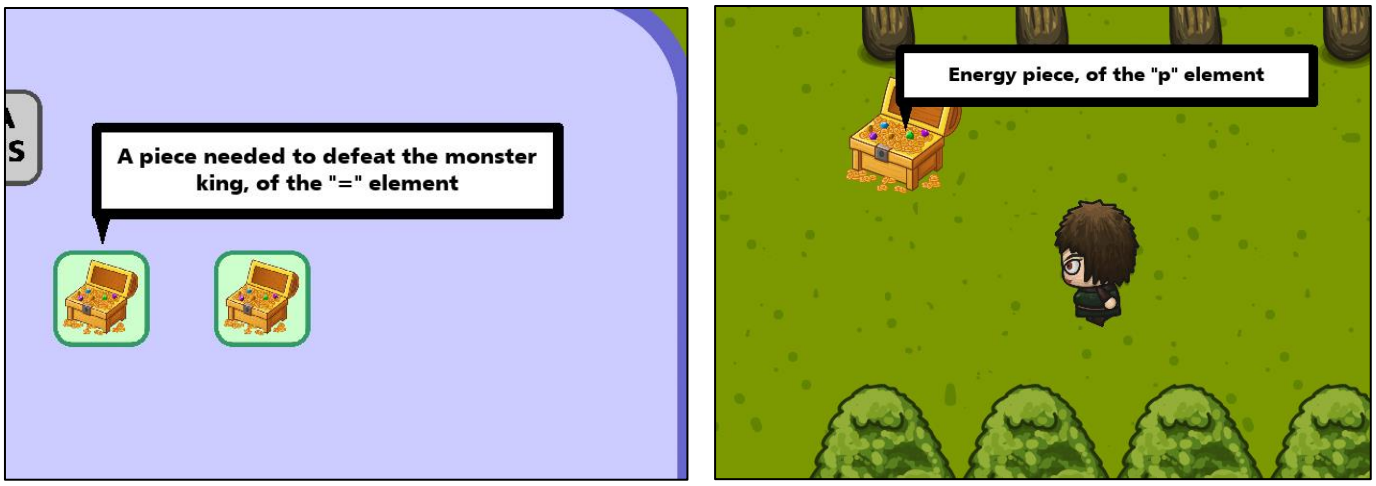
Figure 6 shows two ways the game informs the player of an energy piece's learning element. First, the player can open an inventory screen, which lists all pieces the player has gathered. By pointing the mouse cursor at a piece, the player can see the learning element assigned to the piece. Likewise, pointing the cursor at a piece on the ground will show the piece's learning element.

Figure 7 shows a code snippet of an elder's event, which runs when the elder describes a lesson on the dialog box. First, an introductory speech mentioning the lesson's name, acquired from a function call on line 261, is composed. Second, the actual description of the lesson is requested with another function call on line 265. The whole dialog text constitutes the parameter for the event declaration on line 266. Consequently, changing which lesson the elder explains will be trivial, as we only need to change the function call parameters.



(a) (b)

Figure 5. Dialogs with the Village Chief (a) and One of the Elders (b)



(a) (b)

Figure 6. Two Ways for the Player to Check an Energy Piece's Learning Element: on the Inventory Screen (a) and the Game Screen (b) by Pointing the Mouse Cursor at the Piece

```
261  lvArrayText[0] = "According to an ancient tome, the power of " + funLessonNameGet(0)
262      + " is as follows ....";
263  //get the description of the learning rule
264  //call a function here
265  lvArrayText[1] = funLessonDescriptionGet(0);
266  var lvEvent = new funEventTypeDialog(lvArrayText, vPic, vName);
```

Figure 7. The Connection between an Elder and a Lesson's Name and Description in the Game's Code

3.2 Questionnaire Results

Table 4 shows the results of the GUESS-based questionnaire. We can see that the participants rated the Usability, Creative Freedom, and Narrative factors somewhat favorably. On the other hand, the Play Engrossment one scored the lowest, although not by a wide margin. Cronbach's alphas of Creative Freedom and Narrative far exceed the minimum reliable value of 0.65 [38], whereas those of Usability and Play Engrossment are not far behind. Overall, we can conclude that our RPG was successful in entertaining the participants.

Table 5, Table 6, and Table 7 show the results of the EGameFlow-based questionnaires for the three learning topics. We can see that the participants had moderately good learning experiences for both propositional logic and software development topics. Despite being foreign to first-year Informatics students, software development seems to be an appropriate learning topic for our RPG. On the other hand, the algorithm topic acquires visibly lower means than

the other two on all factors. The very high Cronbach's alphas suggest that the results reliably reflect the participants' view toward the topic's lessons. On the other hand, the propositional logic's Challenge factor, with a below-standard alpha, may have been heterogeneous [39], i.e., influenced by irrelevant variables. That the software development and algorithm topics both acquire high alphas on the factor suggests that the variables may be related to familiarity.

From the results, we can conclude three things:

1. Both familiar and unfamiliar learning contents are equally suitable for medium-coupling educational games;
2. The game should present familiar learning content in a way that prevents the familiarity from over-influencing the learning process;
3. Cryptic and hard-to-memorize learning content should be avoided unless the game can mitigate the adverse effects.

Table 4. Results of the GUESS-based Questionnaire

Factor	Aggregated Mean	Standard Deviation	Cronbach's Alpha
Usability/Playability	5.74	1.49	0.661
Play Engrossment	4.93	1.69	0.662
Creative Freedom	5.23	1.43	0.772
Narrative	5.29	1.47	0.868

Table 5. Results of the EGameFlow-based Questionnaire for the Propositional Logic Topic

Factor	Aggregated Mean	Standard Deviation	Cronbach's Alpha
Knowledge Improvement	5.80	1.24	0.747
Challenge	5.55	1.23	0.580
Autonomy	5.02	1.31	-

Table 6. Results of the EGameFlow-based Questionnaire for the Software Development Topic

Factor	Aggregated Mean	Standard Deviation	Cronbach's Alpha
Knowledge Improvement	5.62	1.42	0.909
Challenge	5.32	1.41	0.858
Autonomy	5.10	1.44	-

Table 7. Results of the EGameFlow-based Questionnaire for the Algorithms Topic

Factor	Aggregated Mean	Standard Deviation	Cronbach's Alpha
Knowledge Improvement	4.79	2.20	0.968
Challenge	4.37	2.06	0.964
Autonomy	4.36	2.09	-

3.3 Critiques and Suggestions from the Participants

From the discussion with the participants, we gathered many insightful comments, critiques, and suggestions. We have condensed critiques and suggestions that are similar in meaning to one theme. Table 8 shows the resulting eleven themes and their distributions among the participants. The top five themes are in light green. As each participant could give more than one critique or suggestion, the total number at the bottom of the table exceeds the number of participants.

Among the themes, "game content" refers to both gameplay- and narrative-related elements. Suggestions for more game content are the most popular, with "more" refers to either specific game features, e.g., new weapons, or game content in general, e.g., a larger game world. We separate "different game content for different learning topics" from "more game content" as the latter does not specify if the larger content quantity should be divided among learning topics. Other than quantity, some participants also demanded more engaging game content, e.g., requiring strategies.

On the matter of learning content, many participants asked for better ways to interact with learning elements. These suggestions range from less clunky ways to inspect a pickable item's learning element (i.e., not having to point the mouse cursor at the item) to options for re-ordering acquired elements. Some participants also expressed confusion and frustration from understanding the lessons, which calls for better ways to present the lessons. The ways potentially include demonstrations of the lessons, which can be integrated into the game content, e.g., performed by NPCs as part of the narrative. On the other hand, only two participants asked for integration between learning content and game content, suggesting that such integration is inessential for medium-coupling games.

Table 8. Distribution of Participants' Critiques and Suggestions Across Themes

No.	Theme	Number of Participants	%
1	Better ways to interact with learning elements	12	17.14
2	More game content	13	18.57
3	More lessons	1	1.43
4	More varied lesson types	1	1.43
5	More engaging game content	11	15.71
6	Better lesson presentation	7	10.00
7	Different game content for different learning topics	9	12.86
8	Learning content integrated with game content	2	2.86
9	Better control scheme	6	8.57
10	Better interfaces	6	8.57
11	Guides for the player	2	2.86
	Total	70	100.00

3.4 Design Principles for Medium-Coupling Educational Games

Based on the findings related to the questionnaire's results and the critiques and suggestions, we propose five design principles as follows:

1. *Present learning content in challenging manners for players with or without prior knowledge of the content:* To mitigate prior knowledge dependence, the developer can provide various in-game hints and guidance for players lacking such knowledge. On the other hand, the more knowledgeable players should be free to ignore the hints and guidance. Facilitating those contrasting playstyles is indeed beneficial in serious games [40]. Regarding our framework, game interfaces can show various *help resources*, which should be discreet, optional, and available on-demand and at the right times [41][42]. The game can also utilize objects for the purpose. Other than NPCs, various other types of game objects, e.g., books and street signs, are also viable. Like the interface-based help resources, the objects should be skippable and appear at the right times, e.g., before the player needs to exercise a new mechanic. Regardless of how the hints and guidance are presented, they will inevitably draw upon extensive *lesson descriptions*. As Rosyid et al. suggested [9], the developer can also annotate the descriptions to automate their integration into game content.
2. *Present lessons in easy-to-understand and non-burdening ways:* Like the first principle, this one is also about providing hints and guidance. However, this principle is more about the hints and guidance's *effective* presentation. Instead of one NPC explaining a particular lesson, the game can explain it through numerous NPCs. Instead of concentrating a lesson description in one place, the developer can spread it across various game objects, which the player gradually meets as they play. This distributed presentation strategy aligns with [40] and the game design principle of appropriate pacing [43].
3. *Provide game content of sufficient variety and quantity to facilitate many learning contents:* Flexibly facilitating different learning contents is meaningless if the game does not have extensive and varied game content to keep each learning content fresh. In our framework, the game content components in question are game mechanics and objects. In addition to providing more game content quantity, the developer can also split the content into different groups (e.g., episodes of a long narrative) for different game sessions.
4. *Maximize the game content's fun factor to keep players engaged over many game sessions:* Varied and extensive game content will quickly bore the player if it has no depth. As discussed earlier, the depth and fun factor are determined by game loops. In our RPG case, we can add more weapons with different mechanics (e.g., a grenade has to be aimed before thrown) and more diverse and challenging enemies to make the combat-related loop harder to master. We can also increase the dialog mechanic's complexity (e.g., by enriching the dialog events and adding dialog choices to make the NPCs like or dislike the player) to turn it into the third game loop. Fortunately, since a medium-coupling game's learning content is not tightly integrated with its core mechanics, the developer can freely refine its game loops without disrupting its educational aspect.
5. *Provide various ways to interact with the learning content:* Generally, a game player should never feel that their inability to play as intended is due to the game system's deficiencies, e.g., overly-limited ways to interact with and modify learning content. We can classify the interactions into two: those manipulating the game states and those informing the player about the learning content. We will give two examples related to our RPG. In addition to the mouse cursor, we can add a keyboard button to display an energy piece's learning element. Another possible way to see the information is by positioning the player's avatar on top of the piece. Meanwhile, our RPG currently provides only one way to manage the player's energy pieces: erasing them by clicking a button on the inventory screen. As one participant suggested, we can add ways to rearrange the pieces and erase only specific ones.

4. Conclusion

Educational games hold a tremendous potential for education in the 21st-century, yet cost issues hamper their applications. The medium-coupling approach, which partially integrates learning content with game content for engaging yet economical educational games, is a promising solution to the problem. This study has contributed to the approach's scant body of knowledge by proposing a design framework for medium-coupling educational games. The framework concisely shows how to connect game mechanics, objects, states, and interfaces to learning elements and lessons' rules and descriptions. We have validated the framework by applying it to design and develop an educational role-playing game (RPG). The RPG presented three learning topics with different characteristics as parts of its heroic-themed narrative. Sixty first-year Informatics students tested the game, filled a post-test questionnaire, and participated in a discussion. The questionnaire's results validate the game's entertainment and educational values while also uncovering how it works under different learning contents. The discussion gathered insightful suggestions and critiques, with the prominent ones related to game content's quantity, variety, fun factor, and learning content presentation and interaction methods. Together with the questionnaire's results, we synthesize the suggestions and critiques into usage principles of our framework.

Meanwhile, we have also discussed how games created under the framework can be cost-efficient in facilitating different learning contents. Although we have shown the efficiency in our RPG's design and code, it is limited to cases where the learning contents are similar. Adapting medium-coupling games to learning contents with drastic differences, e.g., in their element arrangement rules, is a topic for extensive studies in the future.

Other than the adaptation problem, we see other promising directions for future studies. The framework can be validated further by applying it to design games of other genres. We can also employ more complex game mechanics, e.g., an elaborate quest system [44], which will benefit both the game's educational and entertainment aspects. Tapping into the vast realm of procedural content generation (PCG) for novel cost-reduction methods is also on our agenda. Some potential uses of PCG are generating new mechanics [45], narratives [46], the correct positions of objects representing learning elements [47], and in-game tutorials [48], possibly from lesson rules with the help of *natural language generation* [49]. It will also be fruitful to compare a medium-coupling game with an intrinsically-integrated one, which may uncover which learning contents the former excels at facilitating. Lastly, we will also explore tailoring the games to individual players' needs, one of the hottest issues in educational games [50].

Acknowledgment

This research work was supported by a Riset Dasar (RISDA) Lanjutan grant from University of Pembangunan Nasional "Veteran" Jawa Timur.

References

[1] F. Laamarti, M. Eid, and A. El Saddik, "An Overview of Serious Games," *International Journal of Computer Games Technology*, 2014. https://doi.org/10.1155/2014/358152
[2] S. S. Adkins, "The 2018-2023 Global Game-based Learning Market: Worldwide Serious Game Industry in a Boom Phase," Serious Play Conference, 2019.
[3] T. Hainey, T. M. Connolly, E. A. Boyle, A. Wilson, and A. Razak, "A systematic literature review of games-based learning empirical evidence in primary education," *Computers and Education*, vol. 102, pp. 202–223, 2016. https://doi.org/10.1016/j.compedu.2016.09.001
[4] J. L. Plass, B. D. Homer, and C. K. Kinzer, "Foundations of Game-Based Learning," *Educational Psychologist*, vol. 50, no. 4, pp. 258–283, 2015. https://doi.org/10.1080/00461520.2015.1122533
[5] P.-M. Noemí and S. H. Máximo, "Educational games for learning," *Universal Journal of Educational Research*, vol. 2, no. 3, pp. 230–238, 2014.
[6] E. A. Boyle *et al.*, "An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games," *Computers and Education*, vol. 94, pp. 178–192, 2016. https://doi.org/10.1016/j.compedu.2015.11.003
[7] D. B. Clark, E. E. Tanner-Smith, and S. S. Killingsworth, "Digital Games, Design, and Learning: A Systematic Review and Meta-Analysis," *Review of Educational Research*, vol. 86, no. 1, pp. 79–122, 2016. https://doi.org/10.3102%2F0034654315582065
[8] M. Freire, Á. Serrano-Laguna, B. M. Iglesias, I. Martínez-Ortiz, P. Moreno-Ger, and B. Fernández-Manjón, "Game Learning Analytics: Learning Analytics for Serious Games," in *Learning, Design, and Technology*, 2016, pp. 1–29. https://doi.org/10.1007/978-3-319-17727-4_21-1
[9] H. A. Rosyid, M. Palmerlee, and K. Chen, "Deploying learning materials to game content for serious education game development: A case study," *Entertainment Computing*, vol. 26, pp. 1–9, 2018. https://doi.org/10.1016/j.entcom.2018.01.001
[10] Z. Peddycord-Liu, R. Harred, S. Karamarkovich, T. Barnes, C. Lynch, and T. Rutherford, "Learning Curve Analysis in a Large-Scale, Drill-and-Practice Serious Math Game: Where Is Learning Support Needed?," in *Artificial Intelligence in Education. AIED 2018. Lecture Notes in Computer Science, vol 10947*, 2018, pp. 436–449. https://doi.org/10.1007/978-3-319-93843-1_32
[11] S. Vandercruysse and J. Elen, "Towards a Game-Based Learning Instructional Design Model Focusing on Integration," in *Instructional Techniques to Facilitate Learning and Motivation of Serious Games*, Springer International Publishing, 2017, pp. 17–35. https://doi.org/10.1007/978-3-319-39298-1_2
[12] J. Habgood and S. E. Ainsworth, "Motivating children to learn effectively: Exploring the value of intrinsic integration in educational games," *Journal of the Learning Sciences*, vol. 20, no. 2, pp. 169–206, 2011. https://doi.org/10.1080/10508406.2010.508029
[13] A. Echeverría, E. Barrios, M. Nussbaum, M. Améstica, and S. Leclerc, "The atomic intrinsic integration approach: A structured methodology for the design of games for the conceptual understanding of physics," *Computers and Education*, vol. 59, no. 2, pp. 806–816, 2012. https://doi.org/10.1016/j.compedu.2012.03.025
[14] O. Ku, S. Y. Chen, D. H. Wu, A. C. C. Lao, and T. W. Chan, "The effects of game-based learning on mathematical confidence and performance: High ability vs. low ability," *Educational Technology and Society*, vol. 17, no. 3, pp. 65–78, 2014.

[15] V. Garneli, C. Sotides, K. Patiniotis, I. Deliyannis, and K. Chorianopoulos, "Designing a 2D Platform Game with Mathematics Curriculum," in *Games and Learning Alliance. GALA 2019. Lecture Notes in Computer Science, vol 11899*, Springer, Cham, 2019, pp. 42–51. https://doi.org/10.1007/978-3-030-34350-7_5
[16] V. Beserra, M. Nussbaum, R. Zeni, W. Rodriguez, and G. Wurman, "Practising arithmetic using educational video games with an interpersonal computer," *Educational Technology and Society*, vol. 17, no. 3, pp. 343–358, 2014.
[17] P. W. Atmaja, F. Muttaqin, and S. Sugiarto, "Facilitating educational contents of different subjects with context-agnostic educational game: A pilot case study," *Register: Jurnal Ilmiah Teknologi Sistem Informasi*, vol. 6, no. 1, pp. 53–65, 2020. https://doi.org/10.26594/register.v6i1.1726
[18] Z. O'Shea and J. Freeman, "Game design frameworks: Where do we start?," in *FDG '19: Proceedings of the 14th International Conference on the Foundations of Digital Games*, 2019. https://doi.org/10.1145/3337722.3337753
[19] F. Ke, "Designing and integrating purposeful learning in game play: a systematic review," *Educational Technology Research and Development*, vol. 64, no. 2, pp. 219–244, 2016. http://dx.doi.org/10.1007/s11423-015-9418-1
[20] F. Ke, K. Xie, and Y. Xie, "Game-based learning engagement: A theory- and data-driven exploration," *British Journal of Educational Technology*, vol. 47, no. 6, pp. 1183–1201, 2016. https://doi.org/10.1111/bjet.12314
[21] Y. R. Shi and J. L. Shih, "Game Factors and Game-Based Learning Design Model," *International Journal of Computer Games Technology*, vol. 2015. 2015. https://doi.org/10.1155/2015/549684
[22] J. N. Proulx, M. Romero, and S. Arnab, "Learning Mechanics and Game Mechanics Under the Perspective of Self-Determination Theory to Foster Motivation in Digital Game Based Learning," *Simulation and Gaming*, vol. 48, no. 1, pp. 81–97, 2017. https://doi.org/10.1177%2F1046878116674399
[23] M. B. Carvalho *et al.*, "An activity theory-based model for serious games analysis and conceptual design," *Computers and Education*, vol. 87, pp. 166–181, 2015. https://doi.org/10.1016/j.compedu.2015.03.023
[24] M. Sailer, J. U. Hense, S. K. Mayr, and H. Mandl, "How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction," *Computers in Human Behavior*, vol. 69, pp. 371–380, 2017. https://doi.org/10.1016/j.chb.2016.12.033
[25] S. Heintz and E. L. C. Law, "Digital educational games: Methodologies for evaluating the impact of game type," *ACM Transactions on Computer-Human Interaction*, vol. 25, no. 2, 2018. https://doi.org/10.1145/3177881
[26] J. L. Plass *et al.*, "The effect of learning mechanics design on learning outcomes in a computer-based geometry game," in *E-Learning and Games for Training, Education, Health and Sports. Edutainment 2012, GameDays 2012*, 2012, vol. 7516 LNCS, pp. 65–71. https://doi.org/10.1007/978-3-642-33466-5_7
[27] C. Busch, L. Dohrmann, M. Möhlihs, M. Pasadu, and M. Steinicke, "Design-based research on conceptually integrated games to foster chemistry skills in secondary education," in *Proceedings of the European Conference on Games-based Learning*, 2016, pp. 89–97.
[28] Z. Alaswad and L. Nadolny, "Designing for Game-Based Learning: The Effective Integration of Technology to Support Learning," *Journal of Educational Technology Systems*, vol. 43, no. 4, pp. 389–402, 2015. https://doi.org/10.1177%2F0047239515588164
[29] B. Morschheuser, L. Hassan, K. Werder, and J. Hamari, "How to design gamification? A method for engineering gamified software," *Information and Software Technology*, vol. 95, no. April 2017, pp. 219–237, 2018. https://doi.org/10.1016/j.infsof.2017.10.015
[30] M. Sicart, "Defining game mechanics," *Game Studies*, vol. 8, no. 2, 2008.
[31] E. Adams and J. Dormans, *Game Mechanics: Advanced Game Design*. New Riders, Berkeley, CA, 2012.
[32] E. Adams, *Fundamentals of Game Design, Third Edition*. New Riders, 2014.
[33] K. Wegner, S. Seele, H. Buhler, S. Misztal, R. Herpers, and J. Schild, "Comparison of Two Inventory Design Concepts in a Collaborative Virtual Reality Serious Game," in *CHI PLAY '17 Extended Abstracts: Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play*, 2017, pp. 323–329. https://doi.org/10.1145/3130859.3131300
[34] J. P. Zagal and S. Deterding, "Definitions of 'Role-Playing Games,'" in *Role-Playing Game Studies: Transmedia Foundations*, Routledge, 2018, pp. 19–51. https://doi.org/10.4324/9781315637532-2
[35] M. Sicart, "Loops and Metagames: Understanding Game Design Structures," *Foundations of Digital Games*, 2015.
[36] M. H. Phan, J. R. Keebler, and B. S. Chaparro, "The Development and Validation of the Game User Experience Satisfaction Scale (GUESS)," *Human Factors*, vol. 58, no. 8, pp. 1217–1247, 2016. https://doi.org/10.1177%2F0018720816669646
[37] F. L. Fu, R. C. Su, and S. C. Yu, "EGameFlow: A scale to measure learners' enjoyment of e-learning games," *Computers and Education*, vol. 52, no. 1, pp. 101–112, 2009. https://doi.org/10.1016/j.compedu.2008.07.004
[38] J. J. Vaske, J. Beaman, and C. C. Sponarski, "Rethinking Internal Consistency in Cronbach's Alpha," *Leisure Sciences*, 2017. https://doi.org/10.1080/01490400.2015.1127189
[39] M. Tavakol and R. Dennick, "Making sense of Cronbach's alpha," *International Journal of Medical Education*, vol. 2, pp. 53–55, Jun. 2011. https://dx.doi.org/10.5116%2Fijme.4dfb.8dfd
[40] A. De Gloria, F. Bellotti, and R. Berta, "Serious Games for education and training," *International Journal of Serious Games*, vol. 1, no. 1, Feb. 2014. https://doi.org/10.17083/ijsg.v1i1.11
[41] L. F. de Oliveira, L. S. Espindola, C. Q. Santos, A. C. A. Ziesemer, L. Müller, and M. S. Silveira, "Help Resources in Games: Gamers' Opinions and Preliminary Design Remarks," in *Proceedings of the XVI Brazilian Symposium on Human Factors in Computing Systems*, 2017. https://doi.org/10.1145/3160504.3160572
[42] E. Andersen *et al.*, "The impact of tutorials on games of varying complexity," in *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*, 2012, pp. 59–68. https://doi.org/10.1145/2207676.2207687
[43] P. Sweetser, D. Johnson, P. Wyeth, A. Anwar, Y. Meng, and A. Ozdowska, "GameFlow in Different Game Genres and Platforms," *Computers in Entertainment*, vol. 15, no. 3, Apr. 2017. https://doi.org/10.1145/3034780
[44] G. Smith *et al.*, "Situating quests: Design patterns for quest and level design in role-playing games," in *Interactive Storytelling. ICIDS 2011*, 2011, vol. 7069 LNCS, pp. 326–329. https://doi.org/10.1007/978-3-642-25289-1_40
[45] A. Zook and M. Riedl, "Generating and Adapting Game Mechanics," *Proceedings of the 2014 Foundations of Digital Games Workshop on Procedural Content Generation in Games*, 2014.
[46] B. Kybartas and R. Bidarra, "A Survey on Story Generation Techniques for Authoring Computational Narratives," *IEEE Transactions on Computational Intelligence and AI in Games*, vol. 9, no. 3, pp. 239–253, 2017. https://doi.org/10.1109/TCIAIG.2016.2546063
[47] P. W. Atmaja and Sugiarto, "Generating Object Placements for Optimum Exploration and Unpredictability in Medium-Coupling Educational Games," in *2020 International Conference on Innovation and Intelligence for Informatics, Computing and Technologies (3ICT)*, 2020. https://doi.org/10.1109/3ICT51146.2020.9311976
[48] M. Green, A. Khalifa, G. Barros, and J. Togellius, "'Press Space to Fire': Automatic Video Game Tutorial Generation," in *Proceedings of the AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment, vol. 13, no. 1*, 2017, pp. 75–80.

[49] A. Gatt and E. Krahmer, "Survey of the State of the Art in Natural Language Generation: Core tasks, applications and evaluation," *Journal of Artificial Intelligence Research*, vol. 61, pp. 65–170, Jan. 2018.

[50] D. Hooshyar, M. Yousefi, and H. Lim, "A systematic review of data-driven approaches in player modeling of educational games," *Artificial Intelligence Review*, vol. 52, no. 3, pp. 1997–2017, Oct. 2019. https://doi.org/10.1007/s10462-017-9609-8