The Ludo-Learning Matrix: A Framework for Understanding Learning in Games

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Abstract: Games have been widely recognized as methods of making learning more engaging. This has proven to be very attractive to those attempting to get complex fields such as cybersecurity training to a wider audience. Unfortunately, there is a failure to understand that each type of game serves a different educational purpose, leading to the situation where the games are being selected incorrectly and are failing to fulfill their promise. To address this issue, key concepts in learning and games were identified from the literature and then operationalized into an analytical framework. The concepts of player agency, message broadcasting, the transfer of learning and the type of challenges present in the game were selected. This generated a framework that is player-focused rather than content-focused and could be applied to any potential learning game. To validate the framework, three cybersecurity games were selected and analyzed using a ludo-textual approach. *Cyberciege*, a single player game aimed at university students, *Spoofy*, a kids' web browser game and *Tallinn Soldier*, a seminar wargame, were selected to give as wide a sample as possible. The paper goes on to report on the results of the analysis and discuss how this may be used to examine and design learning games for cybersecurity in the future. Each of the selected games focus on different mechanisms for learning and engagement, highlighting the design tradeoffs that were made in the creation of the game. The proposed analytical framework can be applied not just to cybersecurity training games but theoretically to understanding any game that has learning as its objective.

1. Introduction

Complex fields like cybersecurity exist between multiple domains requiring not just technical training and skills but an understanding of how humans leverage these technologies for illicit purposes. In addition, with the wide range of people using the internet for everyday life, an understanding of the principles of cybersecurity has become essential. The combination of a complex subject area and heterogenous population has led to concerns about making sure that the education is engaging. Game based learning has been seen as a possible solution (Jin et al., 2018). It is hoped that the use of game-based learning methods will help to increase the engagement with and interaction between the students and the subject matter.

However, selecting games, as with selecting any content, to include in education is a difficult process. A incorrectly selected game may lead to the player internalizing incorrect assumptions or procedures. This can occur because not all games map to the same intended learning outcomes. While the focus of the content area may be the same for multiple games, the approach to learning that they take varies dramatically. This leaves an educator in the unenviable position of not knowing how to select the correct game for their context.

Existing frameworks tend to be focused on the learning content of the games. In many regards they see games as the delivery system for knowledge similar to how Clark viewed media for the purpose of education (Kozma, 1994). These frameworks to select and design games for learning often borrow heavily from instructional design frameworks such as A.D.D.I.E. (Drljača et al., 2017). This produces a very instructor-centric form of design, which may fail to understand what is engaging for the end user in the first place.

Katrin Becker provides her magic bullet model. It focuses on what must be learned to engage with the game, what can be learned through engaging and what external support is needed for the game (Becker, 2017). While this provides a useful method to analyse and understand a game, it ignores the action that the player is going to take in the game and underplays the different pathways that knowledge can be acquired through.

The research into how games promote learning and engagement, however, tends to be highly theoretical and as such not actionable. Gee (2007) proposes 36 learning principles that are embedded in games. Garris et al., (2002) identified 39 different game elements which were condensed to 18 different elements that were mapped to learning by Wilson et al. (Bedwell et al., 2012). Unfortunately, the sheer number of elements in these works make the production of an actionable mental model to understand how a game is promoting learning next to impossible.

This lack of clarity also produces problems for learning game designers. Without a clear mental model of how games are engaging the player in learning, it is difficult if not impossible to design a game to reach a specific objective. Equally, efforts to build off of preexisting games and to repurpose them are hampered by not having

a clear idea of the game from the players' perspective. This leads to situations where every designer is in effect designing in isolation and having to rely on just personal experience in design.

The validity of any framework is another consideration. The model must be capable of differentiating between the learning happening in a wide variety of games, even if they are in a similar genre or content area. The best way to ensure that any framework is valid and robust is to test it against actual games using a ludo-textual analysis (Booth, 2021).

This paper proposes a simple and robust matrix for the analysis and design of learning games. It identifies four key concepts taken from both educational theory and game design and operationalises them. It then shows through a ludo-textual analysis of three games from the same content area how the framework can highlight the different design decisions that have been made.

2. Methodology

Four key concepts found in both learning and games were selected from the literature. A discussion of why each concept was selected is included in the appropriate description in the results. The selection process was described in Callaghan (2022). The key concepts were: 1) the transfer of knowledge, 2) the type of challenge present, 3) the level of agency the player experiences and 4) the type of message being broadcast by the game. Each of these elements was found to have two sub-components, leading to eight operationalised questions to produce the Ludo-Learning Matrix (presented in Table 1).

To keep the matrix at a usable size, certain concepts had to be excluded from the framework. In general, elements were excluded for one of two reasons. One reason is that some elements focused too much on the content of the game rather than on what the player was engaging with. For this reason, elements such as Fantasy, Mystery and Surprise as found in Bedwell (2012) and mirrored in Malone (1981) were excluded. The second reason was that they were already being covered by the proposed labels. For this reason, concepts such as Flow (Csikszentmihalyi, 1991) and the Zone of Proximal Development (Vygotskii & Vygotskiæi, 2012) were rejected as discrete labels, since they were represented in the conceptualization of challenge (Denisova et al., 2020).

To validate the proposed matrix, a ludo-textual analysis, as outlined by Booth (Booth, 2021), was performed. Three games all from the content area of cybersecurity were selected to see if the framework could be used to examine the differences in approach used by their designers. Each game was played multiple times by the author and, in the case of *Tallinn Soldier*, a selection of Master's students in Learning Game Design. Data was captured using video recording and the think-aloud method, as well as notes taken during and after play. The metatextual elements around the game were also explored to ensure thorough understanding of the games and their principles.

2.1 Selection of Games for Analysis

The first criterion for selection was that the game was designed as a serious game: this excluded commercial off the shelf games from this current work. The next criterion for selection was availability: games like *Anti Phisihing Phill (Online Game Helps People Recognize Internet Scams, n.d.)* were rejected due to the cost of their license, and other games that were identified in the literature had to be excluded because copies of the game were not available. Finally, it was decided that as wide a sample of games as possible should be selected in terms of genre, target audience and themes. Three games—*Cyberciege*, *Spoofy* and *Tallinn Soldier*—were selected.

2.2 Cyberciege https://nps.edu/web/c3o/cyberciege

Cyberciege is a workplace simulator, which asks the player to take the role of an executive in charge of the cybersecurity of a small to medium enterprise. The player must decide how to spend resources (money and work tasks) to secure the network and prevent intrusions. It is aimed at an audience of university level students and includes a full 3D environmental representation.

2.3 *Spoofy* https://spoofy.ee/en

Spoofy is a point and click adventure game. The player is trying to gather the components of a spaceship that have been mysteriously scattered across several levels. They do this by interacting with the non-player characters and helping them to solve problems related to the issues around cybersecurity. The audience for this

game is primary school-aged children and the art style is a 2D cartoon style. Originally, there were four levels that a player could play, with a fifth level released in October 2023 (post the study).

2.4 Tallinn Soldier

Tallinn Soldier is an analog seminar-style wargame taken from the Handbook of Cybersecurity Wargaming (Curry & Drage, 2020). It is designed for a group of between 4 and 6 players. Players are presented with printed role cards of the character that they are playing and are then briefed on the situation that is occurring. Players discuss how they would handle the situation and come to an agreement on their course of action. After this, an escalation of the situation occurs and the players must respond again. This game was developed for university level or higher players and is focused on replaying the real-life events of the Bronze Night in 2007 in Estonia.

3. Results

The next sections provide an overview of how the framework was created (3.1) and the analysis of the games using the framework (3.2).

3.1 Transfer of Knowledge

For learning to occur, information must pass from one area to another. The recipient of the information should engage with it actively to help to retain it and to make it actionable. There are many forms of transfer identified in the literature, including positive and negative transfer (Baldwin & Ford, 1988), general and specific transfer (Gick & Holyoak 1987) and horizontal and vertical transfer (Patrick, 1992). It was decided to focus on the low road and high road transfer identified by Salomon & Perkins (1992) and that of far and near transfer as outlined by Ericsson (2010)

Low road transfer is when the context of use closely matches the designed transfer tool. This allows the player to practice for events that may happen in that context in a safe and controlled environment. It also allows for the automatic use of knowledge or skills in the new context.

Similarly, in near transfer the initial learning task is kept as similar as possible to the task to be learned. Examples of these styles of transfer in games are typified by the simulations, especially high end flight simulators.

The key element for near and low road transfer is fidelity of the training to the context of use. In the Ludo-Learning Matrix, this was operationalized into the question: “How closely does the game attempt to reflect reality?”

Far transfer, on the other hand, is where the initial task used to create the learning varies dramatically from the context in which that learning is going to be applied. This meshes well with the concept of high road transfer, which requires the player to make connections between the material that they are being presented with and their experiences of the real world. It requires an active reflective or discussion component for learning to occur. It is not as context-bound in that it is seeking to make connections across context boundaries. This type of learning tends to be more social in nature and practices softer skills.

This was operationalized into: “How much does the game require reflection on the world outside the game?”

3.2 Challenge

“The essence of gameplay is the challenge/action relationship” (Adams 2010).

Challenge has been seen as a primary component of games by many authors, with some going so far as to argue that it is the thing that makes a game a game (Adams 2010.). The challenges tend to map to the cognitive, affective and psychomotor domains of learning.

To operationalize the concept of challenge in games, the study drew on the CORGIS questionnaire on perceived challenge in games (Denisova et al., 2020). It defines four separate types of perceived challenges: 1. cognitive challenge, 2. emotional challenge, 3. performative challenge and 4. decision-making challenge. The concepts of decision-making and emotional challenges were excluded from the operationalization as it mapped very closely to the concept of agency, which was already being included in the framework (as discussed below).

A performative challenge is one which occurs when a game requires rapid and accurate action from the player (Denisova et al., 2020). This was seen as synonymous with twitch reactions and as complementary to the concepts of near and low road transfer.

This was operationalized into: "How much does the game rely on quick decision making?"

A cognitive challenge is when a game requires forward planning, preparation and multitasking. This can be likened to the cognitive load that a player experiences during play. It is also more likely to focus the game on strategic decision-making processes and contemplation in contrast to the quick accuracy required in performative challenges.

This was operationalized into: "How much strategizing is required in playing the game?"

3.3 Messaging

Games are inherently a communicative act. How they differ from other media, however, is that there are two modalities for this communication. Like books and televised media, the messaging can be explicitly encoded. Namely, the message from the sender is made as clear and upfront as possible to prevent polysemy (multiple meanings) and what Eco defines as aberrant decoding from taking place (Munteanu, 2012). This is very similar to the process in instructional design where the intended message or lesson is the end point of the experience. However, as Bogost has pointed out, games also contain a more subtle method of encoding messages through their procedural rhetoric (Bogost, 2007). This is the message that is encoded and transmitted by the way of the game mechanics or how the player interacts with the game artifact. For example, in the *Civilization* series, the mechanics of researching new technologies carries the implicit message that advancement is inherently tied to technological progress and that that progress is linear. It also could be seen as justifying the taking over of less technologically advanced peoples in the name of helping them progress. Procedural rhetoric is a form of encoding that is much more subtle and open to both polysemy and aberrant decoding.

The interplay between these two forms of messaging is complex and interrelated and, in cases one of the two encoding methods, may drown out the messages of the other. An example of this can be seen in the Gundam effect, named after the popular Japanese transmedia franchise, where the softer implicit message of war is bad (a major theme in all the incarnations of the franchise) is being drowned out by the message that giant robots are cool. This can also be seen in games which attempt to promote peace while still making violence appear fun (Dyer-Witheford & De Peuter, 2009).

This can therefore be operationalized into two separate features:

1. Is there an explicit message being promoted by the game? (Explicit messaging)
2. What if any implicit message is being encoded by the procedural rhetoric or rules of the game? (Implicit messaging)

3.4 Agency

Agency can be defined as "the capacity of actors to make practical and normative judgments among alternative possible trajectories of action, in response to the emerging demands, dilemmas, and ambiguities of presently evolving situations." (Emirbayer and Mische, 1998, p. 971)

Agency as a concept in games is similar to the use of autonomy as a component of intrinsic motivation as outlined by self-determination theory (Ryan et al., 2006). When a player has no means of influencing the outcome of a game or becomes aware that the choices that they have are devoid of meaning, the player will disengage. This makes agency an important element of games for teaching, as they are attempting to increase not decrease engagement. Multiple outcomes of the game state will increase the sense of agency, while, conversely, fixed endings decrease the sense of agency.

There are some games which have a fixed outcome or binary outcome that are still engaging in play. Take, for example, chess, where there are only three outcomes: win, lose or draw. However, in the case of chess, the agency is located in how the player chooses to attempt to reach those end conditions. The problem with chess is if a naive player is engaging with a grandmaster, the outcome collapses to a certainty. As the player becomes aware that the ending is preordained, agency falls off, culminating in the old question: why should I bother to play if there is no way for me to win?

This concept can be operationalized into two factors:

1. "Does the game allow for multiple potential endings?" (Agency Choice)
2. "Is the ending balanced between being too predictable or completely random?" (Agency Prediction)

Table 1: Outlines the concepts that make up the framework: a pair of factors for each of the four components.

	Concept	Description	Operationalization
Agency	Choice	The ability of the player to make choices that will impact the outcome of the game.	Does the game allow multiple potential endings that are achievable based on player choices?
	Prediction	The ability of a player to make informed predictions about the value of actions that they are taking while not being certain of the outcome of those actions during play.	Is the player aware of the outcome of the game during play before the outcome is reached?
Messaging	Explicit Message Broadcast	How the designer is encoding explicit messages that the game contains.	What if any message is explicitly stated in the game?
	Implicit message broadcast	How the game mechanics and paratextual elements carry a meaning in the game.	What if any message is being transmitted by how the game is being played?
Transfer of knowledge	Near/low road transfer	The skill and knowledge being transferred is context-bound. The situation in which they are trained is close or nearly identical to the context in which they are to be used. Focused on automaticity of skill use.	How closely does the context of the game mirror reality?
	Far/high road transfer	More context-independent. Relies on the reconceptualization of pre-existing knowledge to the new context in which the skills are to be used.	How much reflection or re-contextualisation is necessary inside the game?
Challenge	Performative challenge	Challenges that require accuracy and speed, often emphasizing fluency of play over thought.	How much does the game rely on quick decision-making?
	Cognitive Challenge	Challenges that require careful thought and consideration while balancing several demands.	How much strategizing is required in playing the game?

3.5 Ludo-textual Analysis

3.5.1 General Comments

The results of the ludo-textual analysis are summarized in Table 2. As expected from the different styles of the games, each displayed different results from the analysis. Some of the variables emerged as co-occurring. For example, games with low agency coincided with games that had stronger explicit messaging; conversely, games with a higher agency had more implicit messaging present. Cognitive challenges were more prominent in games that were attempting high road transfer, while performative challenges were more likely to be linked to efforts at low road transfer. Future work will be needed to establish if these co-occurrences are consistent across a wider variety of games.

Cyberciege: Of the three games, *Cyberciege* was the one which made the most effort to reflect reality. Its setting helped to situate the player in a believable context. It also displayed the most player agency of the games in that it was possible to make the "wrong" decisions. Possibly as a result of this, the level of explicit messaging was low inside the game. It required players to make timely decisions about the spending of resources, and during play there were few opportunities for strategic planning as the events unfolded, throwing up new challenges.

Spoofy: As a point and click adventure, *Spoofy* had an implicit prosocial message that problems can be solved through engaging with the people around you. Its level of agency was more limited than *Cyberciege* in that the player could only choose in which order to engage with the puzzles presented (who do I want to talk to first), but ultimately had to complete all the puzzles to finish the level. Also, the game has only two possible

outcomes—either the player completes the game or they abandon it—thus limiting the agency of the game. To create more of a sense of player agency, the game offers a rewards system of unlocking cosmetic items: hats for the characters to wear in and pets that could be kept in the loading screen area. However, this was separate from the main game and had no effect on its progression. The challenges in the game were more cognitive in nature, as they involved reading and engaging in the story with a high level of reflection on how these events may be similar to personal experiences.

Tallinn Soldier: As opposed to the other two games, *Tallinn Soldier* has a distinct explicit message, which is covered in the historical postscript of the game. The explicit message is that the Bronze Night of 2007 was an unexpected and major defining moment in the history of cybersecurity and cyberwarfare, comparable to watching the nuclear bomb explode in Hiroshima. It also implies that the creation of the NATO Cooperative Cyber Defence Center of Excellence (which is based in Tallinn) was in response to the attacks. *Tallinn Soldier* has the lowest level of player agency out of the three games: the decisions that the player makes have no impact on the outcome of the game or on what is presented next. During playtesting, players quickly realized this and started to pull back from engaging with the game. In terms of challenge, the game is all cognitive challenge, with the essence being the debate between players on what actions to take.

Table 2: Provides an overview of the results of the ludotextual analysis

	Transfer		**Challenge**		**Agency**		**Message**	
	Near low road	**Far High road**	**Performative**	**Cognitive**	**Choice**	**Prediction**	**Explicit**	**Implicit**
Instrumentalised	How close to reality?	How much reflection is required?	How much does it rely on speed and accuracy?	How much strategic planning is needed?	Are there multiple end states reachable by player choice?	Is the game solved or the outcome fixed?	What if any explicit message does the game contain?	What if any message is being transmitted via the mechanics of the game
Game Name								
Cyberciege	Very close to reality. Attempts to make the office environment believable.	Not during game play	Selecting the correct priority and spending resources on it in a timely manner is the essence of the game.	Seems to focus more on doing actions then in long term planning.	Yes. Player choices have direct and measurable impact on the resolution	Obfuscated by the coding	No direct explicit measaging.	You must spend resources to secure a network. The weakest link in a network are the people. You will only get feedback if you get it wrong.
Spoofy	Abstracted to a cartoon world to suit audience	Encourages players to examine situations from own experience	Encourages players to examine situations from own experience	Some planning as there are multiple steps to solve the presented problems	Limited to a binary state. Completed or given up on	Fixed outcome by the nature of the game	No explicit	Prosocial implicit messaging. Problems are solved through communication
Tallinn soldier	Very abstracted from reality	An essential aspect of play.	Accuracy takes second place to discussion	Discussion and debate as the key mode of play. Requires information from outside of the game world	No. fixed beginning and end point player actions have no ability to shape outcome	Readily transparent to the player after turn 2	Explicit messaging contained in debrief section of the game outlining the historic basis for the scenario	Low implicit messaging. Possibly communication as the key to dealing with a crisis.

4. Conclusion

The proposed Ludo-Learning Matrix offers utility to both teachers seeking to use game-based learning and for designers of those learning games. It offers a series of questions that a teacher must engage with before selecting the game for the context. For designers it provides them with insights about how to conceptualize their games before production or how existing games can be used as inspiration for the design of new novel products.

For teachers they must examine the intended learning outcomes of the lesson that the game is supporting. In the area of transfer, it is important to consider if these outcomes require a space to practice discrete skills? Or is it more important to engage the students in discussion? As these two methods require different design decisions in the game. The type of challenge that the teacher is seeking to give their student goes hand in hand with the transfer of knowledge. Physical challenges that require quick responses map to low road transfer. In contrast the more cognitive the challenge the closer it maps to highroad transfer considerations.

In addition, sometimes the learning objectives only require a message to be broadcast. Examples like “Tree” (*TREE*, n.d.) or “One of them” (*One of Them by Pierrec*, n.d.) show that social messaging games do not require as much agency in the player. The purpose of these games can be seen to encourage empathy through a shared experience. However, this may reduce their re-playability or their ability to discuss more nuanced messages

Other times the most important aspect of the learning in the game is the agency and decision making that a student is making. This is especially important for low road transfer games where re-playability acts as reinforcement of the skills that are being practiced. When looking at reinforcement of learning agency becomes a key concept to consider in the selection of the game.

For designer they must ask themselves similar questions because there are different design constraints for each different type of learning game. Low road transfer games can be improved by the addition of stress and time constraints that are anathema to more discussion-based games. In addition, the higher the explicit messaging that is being used in the game the more important story decisions and game mechanic integration have to be considered so that they do not contradict the intended message.

This research presents the first steps in producing a new framework to analyze serious or learning games. As such further research with a wider selection of games will be needed to critically assess the proposed framework and to check its applicability to other fields.

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