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Educators Can Create Effective Learning Games! Evaluating the Effectiveness of Educator-Authored Serious Game

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ABSTRACT

Objective – An educator-oriented Serious Game (SG) authoring tool is designed to enable educators to create SGs without expertise in game development, using educator-friendly features such as a no-code programming approach.
Methodology – The effectiveness of such a tool should be measured by its usability and by the effectiveness of the games it produces. We have developed the ARQS tool, which is suitable for educators, based on prior usability studies.
Findings – In this paper, we present an experimental study comparing games designed by an educator and quiz applications.
Novelty – Findings from the study showed that the games led to greater learning gains, motivation, emotional engagement, and learning experience, suggesting that educators can design effective SGs using our ARQS tool.
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1. Introduction

Numerous studies (e.g., De Freitas, 2018) have shown that SGs are effective at improving various aspects of learners' knowledge acquisition, skills, and affective outcomes. SGs in these studies, however, are usually designed by game professionals for use in controlled environments. Experts in game development are needed due to the complexity of the process and the use of associated tools (e.g., game engines) and skills (e.g., programming). Reducing dependence on these experts would improve SG creation by reducing time, effort, and financial constraints. We have recently developed the ARQS (Authentic Role-playing-game Quest System) tool, which enables educators to develop games without requiring expertise in game development. Usability studies have shown the suitability of this tool for educators (Ahmad & Law, 2021, 2022). However, the evaluation of the games produced has not yet been conducted.

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In this paper, we present findings from an experimental study evaluating the effectiveness of educator-authored games created with our authoring tool. The study aimed to identify improvements in learners' Higher-Order Thinking Skills (HOTS) learning gains, motivation, emotion, and learning experience between educator-authored SGs and non-SG learning tools, and to examine how learners' motivation, emotion, and learning experience influence learning gains. Answering these questions should indicate whether educators can design effective serious games for use as teaching tools.

2. Literature Review

Few SG authoring tools have been proposed; some are intended for use by non-game developers, such as educators. ARQS (Ahmad & Law, 2022) provides a structured development methodology for creating Serious Role-Playing Games (RPGs). The methodology includes configuring the lesson description, learning outcomes, learning quests, game world, and various game objects, such as interactive objects and non-player characters. The learning quest is the most important component of ARQS, in which educators design the game's learning activities. Creating learning quests involves converting authentic learning elements (Herrington & Oliver, 2000) into RPG quests, allowing the inclusion of complex real-world tasks as game challenges (Ahmad et al., 2023). While ARQS is usable for educators, games produced by this tool have yet to be evaluated for their efficacy as teaching tools.

RPG gameplay can be related to various established learning theories. Behaviourist theory focuses on repetition and reinforcement (Schunk, 2012), typically implemented through drill-and-practice gameplay common to most games, including RPGs. Simulations and role-playing, commonly found in RPGs, are forms of modelling related to Social Cognitive theories (Schunk, 2012)suggesting the relevance of RPG as a means for learners to observe model behaviours. Another theory that is highly relevant to RPGs is Constructivism (Cobb & Bowers, 1999), which is concerned with knowledge that is formed based on learners' subjective beliefs and experiences in situations, thus requiring learning situated in context (Bredo, 2006). This theory can be incorporated in RPGs, where learners can engage in simulated real-world situations that relate to learned knowledge (Lainema, 2009).

One limitation of existing educator-authored SG studies is the use of incomparable treatments. The study by (López-Fernández et al., 2021) For example, the control group received a teacher-led lecture with slides, whereas the game group received only an SG. The treatments differ not only in the medium (i.e., SG vs. non-game lectures) but also in the instructional activity (e.g., attempting a quiz vs. listening to lectures). The instructional activities would have a different set of tasks; for example, interacting with the teacher is not available in the game group, and could have disadvantaged them in the first place. According to (Mayer, 2019)The effectiveness of learning activities is determined by instructional design, and students can perform equally well in SG or non-game instruction. Experimental studies comparing SG and non-game learning materials should ensure that the instructional activities are comparable, with the only differences between treatments arising from inherent characteristics of the medium, such as interactivity and an explorable game world.

Another aspect to consider is the extent to which SGs address cognitive domains. Most SG experiments measured Lower-Order Thinking Skills (LOTS), which mainly involve information recall (Boyle et al., 2016). More studies are needed to evaluate the effectiveness of SGs in improving HOTS, including students' ability to analyse, evaluate, and create.

3. Research Methodology

An experimental study was conducted using games designed by an educator and developed on our proposed platform. In this section, the design of the experiment and game intervention will be described.

3.1 Study Design and Participants

Figure 1 shows the procedure of our experiment and analysis. Participants (N=101) were undergraduate students from a technical university in Brunei Darussalam. They were randomly divided into two groups and attended two sessions. Randomisation was carried out using a simple random number generator. The set-up enabled within-subjects analyses by comparing the same group under Game and Non-Game conditions (e.g., Group A Game from Session 1 vs. Group B Control from Session 2). To avoid the memory effect, two related sub-topics were used for each session. A between-subjects analysis was also conducted by comparing groups in session 1 (i.e., Group A Game vs. Group B Control), as this was the first time participants were exposed to study treatments. Each session was completed within 2 hours and conducted within one week.

During recruitment, participants completed the background questionnaire to identify their genre preferences and learning styles. This data is required to establish whether it will influence learners' performance when engaging with the games. The pre- and post-test consisted of the same five constructed-response questions (Arter & McTighe, 2001). The questions mostly addressed the "analyse" and "evaluate" cognitive learning outcome dimensions (Krathwohl, 2002).

At the end of each session, participants completed a post-questionnaire to report on their motivation, emotions, and learning experiences regarding their assigned treatments. The IMI (Intrinsic Motivation Inventory) was adopted to measure motivation. It is a multidimensional scale used to measure users' subjective intrinsic motivation when engaging with any form of target activity (Ryan et al., 1983). SAM (Self-Assessment Manikin) was adopted to measure emotion (Bartosova et al., 2019). It is a common instrument used to assess the valence (i.e., feelings of pleasure), activation (i.e., feelings of excitement), and dominance (i.e., sense of control over the situation) elicited in response to an object or event. Finally, the EGameFlow (EGF) was adopted to measure the learning experience (Fu et al., 2009). It is a scale that measures participants' learning experiences when engaging with SGs and is consequently used to evaluate the effectiveness of SGs in terms of perceived effectiveness across various pedagogical aspects.

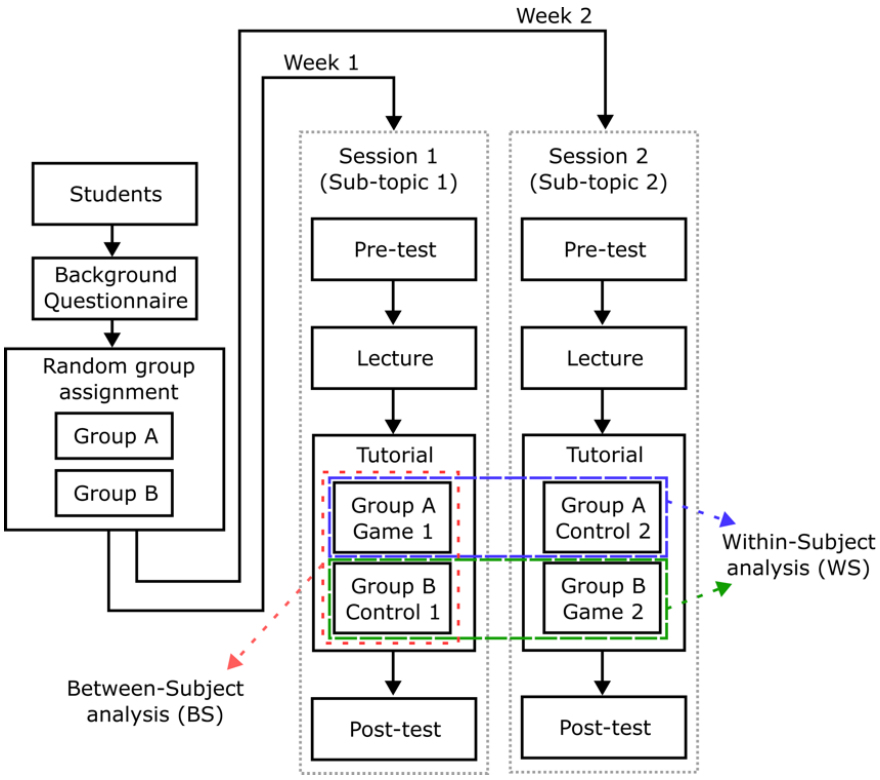

Figure 1. Study Design and Analysis.

3.2 Game Treatment

The games were based on the main topic, "Introduction to Cyber Security," of the undergraduate subject "Information Security Fundamentals" (ISF). Two sub-topics were chosen, "Malware" (for Session 1) and "Basic Network Security" (for Session 2). Both sub-topics share the same learning outcomes, whereby students should be able to analyse potential cyber-attack vulnerabilities in an organisation and advise on appropriate measures to improve an organisation's cybersecurity. The "Malware" sub-topic addresses these learning outcomes: how malware affects an organisation and how to prevent such effects through user awareness. The "Cyber Security" subtopic, on the other hand, addresses these learning outcomes by focusing on the technical hardware and software aspects of improving network infrastructure.

In the games, players assume the role of an IT officer working in a clinic. Players' tasks in the games center on managing the clinic's IT operations within the context of ISF, such as ensuring that devices and network infrastructure are secure. The quests in the game require players to apply concepts from cybersecurity, including malware and its prevention, and to enhance the security of networks and devices using network security hardware and software. The objectives and tasks in these quests were varied (Table 1). One of the quests, for example, involves an activity to teach the concept of "VPN" (Virtual Private Network). In this context, a doctor at the clinic is attending a conference and wants to access the clinic's system to complete some work while he is away. Players then engage in a conversation with the IT department supervisor, who asks for players' opinions on the best approach to do this while ensuring the security of their system. This requires players to select "VPN" as a response (i.e., MCQ task). Players then need to implement a VPN by installing a VPN server on the clinic's server machine and a VPN client on the doctor's personal laptop to ensure a safe connection to the system. To perform this activity correctly, players must first obtain a VPN hardware server from the IT office, install it on a server in the server room, then go

to the doctor's house and use his laptop to download and install the VPN client and connect to the VPN server.

4. Results

To ensure the internal consistency of the IMI and EGF instruments, Cronbach's Alpha was calculated for each of the sub-scales found in the instruments. All subscales showed acceptable reliability (αα> 0.7) and were therefore retained in the final analysis. Table 2 presents the statistical tests conducted to compare learning gains, motivation, emotion, and learning experience across the groups. Learning gains (post-test minus pre-test marks) were statistically different ($p < 0.05$) across all groups for both treatments in the WS analysis, but the games' meaning differences and effect sizes were larger. This implies that the games yielded greater learning gains. All motivation dimensions except "pressure" had higher means in the game, and both the BS and WS analyses showed significant differences for these dimensions, indicating that the game led to higher motivation. This suggests that participants found the game more enjoyable, felt more competent, put in more effort, and perceived it as more useful.

Table 1. Players' tasks and quest objectives in games.

Player Tasks	**Quest Objectives**
Talk to NPC; Answering MCQs; Find an item; Get an Item; Give an Item; Find an NPC; Examine an object; Install a device; Fix or Configure a device; Use a device;	Giving advice; Solving a problem; Fixing a problem; Investigating a problem; Protecting the organisation

All emotion dimensions had higher means in the game, and both the BS and WS analyses also showed significant differences for these dimensions, indicating that the game produced better emotion. This could mean that participants in the game felt happier, more excited, and felt in control of their emotions.

All learning experience dimensions had higher means in the game, and both the BS and WS analyses showed significant differences across these dimensions, indicating that the game led to a better learning experience. This suggests that the games enabled participants to focus more on the activity, understand tasks more clearly, receive useful feedback, feel more in control, feel more immersed, and improve their knowledge.

We also conducted simple linear regression and Pearson correlation analyses to assess whether learning gains were associated with the motivation, emotion, and learning experience dimensions. We found positive, significant relationships with all motivation dimensions except "pressure" and with the learning experience dimensions "concentration", "clarity", and "knowledge". No significant relationship was found between learning gains and emotion. This indicates that learning gains were positively associated with the level of significant motivation and learning experience dimensions.

We also analysed whether learning styles influence learning gains, and whether genre preferences and game-playing experience affect learners' motivation, emotions, and learning experiences when engaging with the games. A one-way ANCOVA was performed, and no significant difference in learning gains was found between the treatments after controlling for the learning style covariate. We identified several significant relationships in which certain genre preferences are associated with motivation, emotion, and learning experience (Table 3).

Table 2. Statistical Tests conducted for the Between-subject and Within-subject analysis.

Data	**Between-subject (BS) Statistical Tests**	**Within-Subject (WS) Statistical Tests**
Learning gains	Mann-Whitney U test	Paired T-test
Motivation	Mann-Whitney U test	Wilcoxon Signed-rank test
Emotion	Mann-Whitney U test	Wilcoxon Signed-rank test
Learning Experience	Mann-Whitney U test	Wilcoxon Signed-rank test

Table 3. Significant Relationship between Motivation, Emotion, and Learning Experience, and Genre Preference. (Nb. + = Positive relationship, - = negative relationship)

Dimension	**Mini**	**Action**	**Adventure**	**RPG**	**Simulation**
Motivation					
Enjoyment	+	+	+	+	+
Competence		+			
Pressure		-			
Usefulness	+	+			
Emotion					
Valence	+	+			
Activation	+				
Dominance		+	+	+	+
Learning Experience					
Concentration		+	+	+	+
Clarity		+	+	+	
Feedback		+	+		+
Autonomy		+	+	+	
Immersion	+	+			+
Knowledge		+	+		

Qualitative feedback regarding the positive and negative aspects of the treatments was also collected (Table 4).

5. Discussion

Our analysis showed that the games yielded greater learning gains, suggesting that they were more effective in improving HOTS. This could be explained by examining the motivations, emotions, and learning experiences perceived by learners. The game had better motivation, and positive relationships between learning gains and the motivation dimensions may suggest that the better motivational aspect afforded by the game led to the better learning gains, which confirm previous study where higher motivation can lead to better learning gains (Tokan & Imakulata, 2019).

The game also had a better learning experience, but only concentration, clarity, and perceived knowledge are positively related to learning gains. This suggests that the game was more effective because it enabled learners to focus more, understand the task better, and improve their knowledge. While learners reported improved emotional well-being during the game, it did not appear to affect learning gains. One possible explanation is that the activity with the treatment and the post-test are treated as two separate activities. Emotion can have a weak association with learning gains when the assessment is not part of the main learning activity (Camacho-Morles et al., 2021).

Table 4. Positive and negative aspects of the treatments.

	Game	**Control**
Positive aspects	Fun, Interesting, Engaging, Game, Exploration, Avatar customisation, Rich Game task, Easy to play, Interactive, Interact with virtual characters, Informative, Real-world scenario, Feedback, solving problems, and Story.	Fun, Engaging, Simple, Quiz, Real-world scenario, Feedback, Interesting topic, and solving problems.
Negative aspects	Limited time, Dislike game, No collaboration, Difficult to explore, Lagging, Small game world, UI feature, Limited avatar customization, Not informative, Challenge, Too easy challenge, Dialog, and Repetitive challenge	Boring, Limited time, No Collaboration, Simple, Typical activity, Too much text, and Feedback.

The better motivation, emotion, and learning experience in the game could be explained by looking at gameplay characteristics that should be present in SGs (Garris et al., 2017) which include fantasy (i.e., fictional stories), goals, sensory stimuli (such as animations and visuals), optimal challenge, mystery, and learner control (i.e., the extent to which players can solve problems). Some of the game's positive attributes (Table 4) were related to these characteristics. The rich tasks found in the game challenges and exploring the game world while completing tasks can be related to the Optimal Challenge, Mystery, and Learner Control characteristics. The use of stories in the games was also noted as a positive aspect. Stories in the game could have also helped learners become more engaged with the learning activity (Aura et al., 2021).

The points above could be further supported by examining the relationships with genre preferences. Many of the motivation, emotion, and learning-experience dimensions were positively associated with genre preferences, particularly action, adventure, RPG, and simulation games. These games commonly share similar properties (Heintz & Law, 2015)suggesting that the educator-designed games shared common traits with entertainment games. This could imply that the high motivational and emotional attributes and perceived learning in the educator’s games are attributable to their similarity to existing games. This may indicate that educators could design SGs that are both entertaining and effective as learning tools.

6. Conclusion

The aim of the experimental study was to evaluate the effectiveness of educator-authored games as a teaching tool using the ARQS framework. The experiment involved undergraduate students undertaking an Information Security module. The results of the experiment have shown positive effects of the games, with better learning gains, motivation, and learning experience than a non-SG digital quiz-based application. This suggests that ARQS enables educators without expertise in game development to design effective SGs that enhance their learning experience and motivation. Although the use of ARQS, used as a structured design guideline and development tool, was found familiar and usable by educators (Ahmad et al., 2023; Ahmad & Law, 2022). Educators need in-depth training, specifically in designing story-based, authentic learning scenarios appropriate to their domains.

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