

Using Game-based Learning Methods to Demystify Cyber Security Concepts for Adult Learners

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Abstract: The digital society we live in today has compelled both businesses and individuals to become increasingly dependent on the internet and online services. With the increasing cyber security threats and attacks, there is a growing demand for cyber security professionals and a need for every individual to be cyber literate and cyber-aware. But cyber security is often regarded as extremely complex and quite technical, which acts as a roadblock in educating the adult population about cyber security. 'Play as a natural means for learning' is commonly exploited in early learning and primary education settings. But it is seldom used in secondary education and rarely considered in an adult learning context. This paper presents a game-based learning resource developed as part of the 'Gamified Intelligent Cyber Aptitude and Skills Training' (GICAST) course to introduce cyber security topics to adult learners. The course is targeted at adult learners who work in low-skilled and low-paid jobs and have no formal degree-level qualification. The aim was to demystify cyber security concepts and equip the low-confidence learners with the confidence to engage in learning and gain additional digital skills to enhance their career options. This paper provides an overview of the GICAST project, the game design principles and the game mechanic employed to achieve the intended pedagogic outcomes. The paper illustrates how the power of games helped demystify a complex area of cyber security among adult learners. This is demonstrated in the evaluation results and findings from the study on the effectiveness of game-based learning methods in enhancing learner engagement and motivation to learn among adult learners.

Keywords: game-based learning; cybergames; adult learning; game design; upskill

1. Background Context

The findings of the cyber-security skills in the UK labour market report by the Department for Digital, Culture, Media & Sport (DCMS) conducted in 2022 indicated an acute shortage of cyber-security professionals in UK following a similar global trend (DCMS, 2022). On the one hand, demand for cyber security professionals is on the rise; on the other hand, COVID-19 has created a substantial economic shock, with millions facing severe threats to their jobs, both immediately and in the longer term. Low-paid workers, particularly those in the sectors that could be displaced by automation, are at risk (Nesta, 2021).

There is a need to boost retraining efforts to address the immediate cyber security skills shortage and bring a diverse range of skills and experiences into the sector. The government has put in strategic measures to address this challenge through its cyber security skills strategy (HM Government, 2022) to widen participation and boost equality and diversity in cyber security careers, mainly by removing barriers to entry and progress for poorly served groups. It is in this context that 'Gamified Intelligent Cyber Aptitude and Skills Training (GICAST)' was funded by the department for education (DfE) and Nesta to develop a game-based learning resource. It was targeted at the low-confidence learners with no formal degree-level qualification, aged between 24-65 years and employed in sectors vulnerable to displacement such as manufacturing, hospitality etc.

GICAST¹ is a badged open course (BOC) hosted on Open Learn Platform² a MOOC platform. The course consists of eight units of study with 24 hours of learning spread across eight weeks. Each unit of study covers a foundational aspect of cyber security for learners to gain fundamental knowledge and an understanding of online safety. Each week, the learning on GICAST begins with a game that the learners play prior to continuing their learning. The games are designed to elicit intuitive responses reflecting the actual action or reaction of the learner in a real-world setting, which helps assess the learner's current security behaviour. In addition, the in-

¹ <https://www.open.edu/openlearn/science-maths-technology/gamified-intelligent-cyber-aptitude-and-skills-training-gicast/content-section-overview?active-tab=description-tab>

² <https://www.open.edu/openlearn/>

game quiz assesses the learner's current knowledge, based on which the learners are directed to an adapted learning pathway. The pathway recommendation is intended to optimise the learner's journey through the course, ensuring they do not spend time on concepts they are already aware of. GICAST did not enforce the recommended adapted learning pathway on the learners, who were free to navigate through the entire content at their own pace and in the order of their preference.

The game-based learning methods employed in the project intend to promote active learning experiences among adult learners and equip them with the confidence to gain additional digital skills to enhance their career options. In this effort, it was essential to demystify a complex area of cyber security for adult learners. This study aims to demonstrate the effects of game-based learning methods on adult learners, particularly their motivation to learn a new skill and enhanced engagement to complete their learning. Section 2 presents a brief literature review on current research that addresses the barriers to learning among adult learners and how game-based learning methods could potentially address any gaps. Section 3 presents the game design and implementation of cyber security game-based learning resources for adult learners. Furthermore, section 4 presents the evaluation methods employed and key findings, and the paper concludes with the key inferences and learning from the project.

2. Related Work

E-learning is the most common delivery method for workforce development and workplace learning (Githens, 2007). Several barriers to learning in the adult learning context hamper them from fully engaging in the e-learning programs. Past negative learning experiences, lack of confidence in using digital technologies and returning to learning after several years of gap demotivates the adult learners from fully engaging in learning and from completing their learning journey.

Two key challenges for educators creating content for adult learners is intrinsic motivation and engagement (Kim, 2009). While game-based learning methods are commonly used in primary and secondary education settings quite successfully Huizenga et al (2009), they are rarely considered in the adult education context, particularly for upskilling the adult population, as with the GICAST project. We will present the work and findings related to game-based learning methods used in adult learning context in the following subsection.

Engagement has been identified as a significant issue with existing training methods to introduce cyber security to adult learners (Reeves, Calic & Delfabbro, 2021; Bada, Sasse & Nurse, 2019). Games, and in particular video games, are known for being engaging activities. Hamari et al. (2016) finds a positive correlation between challenge within game-based learning and the engagement of participants, which further correlates to perceived learning. Ejsing-Duun (2014) concluded that the playful approach in higher education demonstrates that game-based methods allow students' intrinsic motivation towards deep learning while enhancing participation and engagement if balanced with the formal curriculum. Furthermore, reports such as the NMC Horizon Report (Johnson et al., 2014) indicate that educational gameplay has nurtured engagement, critical thinking, creative problem-solving, and motivation to learn. Hence a close look at the various game-based methods will help ensure the right approach is considered to achieve significant results in enhancing engagement and motivation to learn amongst adult learners. A particularly important concept that relates to engagement is that of flow. Flow is a state of increased focus, immersion and efficacy, brought about by a suitably engaging activity (Csikszentmihalyi, 1990). There have been numerous studies into flow, and its impacts on engagement, learning, immersion and enjoyment. Webster, Trevino & Ryan (1993) provide evidence suggesting that flow has a positive impact on learning and help increased engagement with learning.

Challenge is a nother significant factor in the induction of flow, as Jin (2012) determines that challenge contributes towards flow, but only when the challenge is matched to skill level.

An effective cyber security training is interactive (Reeves et al., 2021), and games are usually interactive. A notable advantage of game-based cyber security training is the engagement factor of games, which can also increase motivation to learn (Zhang-Kennedy & Chiasson, 2022). A significant number of game-based cyber security training uses some form of simulation and virtual game world in 2D or 3D (Hendrix et al., 2016)

CyberCEIGE (Irvine, 2011) is a popular simulation-based game that involves simulating a real-world cyber situation, where the learner plays a decision-maker for an organisation.

Another simulation-based game, Anti-Phishing Phil (Sheng *et al.*, 2007), involves sending simulated phishing emails in which the player must decide whether the email is a phishing attempt.

The use of games has been considered in training adult population in cyber security. Zhang-Kennedy & Chiasson (2022) and Hendrix, Al-Sherbaz & Bloom (2016) reviewed multiple game-based tools for cyber security training finding that only a small proportion of investigated tools (fewer than one-third) had been properly evaluated. Hence, we are unable to infer strongly about the effectiveness of game-based methods within the adult learning context. However, there are studies demonstrating the effectiveness of game-based methods in improving engagement and flow among adult learners. In this project, we have designed the games to impart engagement and flow, to demystify a complex subject area such as cyber security and enhance learner experience.

3. Game Design and Development

3.1 Game Design principles

Educational games are often criticised for not integrating learning and gameplay in a balanced way. The learners are either distracted by the gameplay part of a poorly designed game which hinders them from achieving the intended learning outcome and or become disengaged with learning when the learning elements interfere with or corrupt what is enjoyable about the game-based resource (Ke *et al.*, 2019). Therefore, a poor design of game-based learning resources may be counter-productive and a hurdle for learning.

The gameplay constructs within GICAST were designed to include two layers; the narrative layer that employed story-based scenarios and the game mechanics layer that included the rules and actions that governed the narrative. According to Salen and Zimmerman (2005), the gameplay lies in the meaningful interplay between the two layers.

In the context of this project, game-based learning methods were employed to help lower the barriers to learning among the low-confidence adult learners. They may have past negative learning experiences and conscious bias against cyber-security as a highly complex topic to learn. Therefore, it was essential to keep the game mechanics and rules of gameplay simple and not add further barriers while tapping into the power of story-based narratives to make the content relatable to the learners. Many games have a narrative aspiration or tap into the player's memory of previous narrative experiences. The story-based narrative is integrated into the GICAST games in the following three ways:

- as a background plot or mission,
- a localised incident or plot developed within the game-levels
- Partially included the concept of open-ended gameplay by allowing the learners to create their narratives based on the decisions they make during the game.

Each game was designed with a particular narrative; the story behind the game provided the context and link to a specific topic in cyber security. While some games provided a direct link to cyber security concepts, the others were indirect. The games were designed with three types of a narrative (story):

- analogy driven scenario (a parallel between a cyber world and the real world),
- real-life scenarios that involved cyber security decisions we make every day, and
- concepts-driven story.

The final game intended to assess the learner's knowledge and overall learning within the course were based on pure gameplay based on a 'shooting' game mechanic. The design of games used grotesque and fun/humour elements to support engagement and improve knowledge retention, which aligns with findings from previous studies that indicate story-based engagements are known pedagogically to support knowledge retention (Dickey, 2020) (Wouters & Oostendorp, 2013). The elements of 'grotesque' offered an interesting approach to authenticity. The project timeframe and the budget did not allow for high-end visualisation and immersive graphics. Minecraft-style design set the learner's expectation for those from a gaming background that the focus was on narrative and game-logic rather than the visual gaming experience.

3.2 Development of Game-based learning resources

3.2.1 Core Game logic

GICAST is a self-directed badged open course hosted on the Open Learn MOOC platform. GICAST was designed to be Self-directed as students found that the participants benefited from a sense of autonomy and control over the pace and duration of learning when self-directed theory is embedded within game-based learning (Vanduhe, Nat, & Hasan, 2020). This also aligns with works from researchers in adult learning, who highlighted the need for autonomy and the influence of motivation in their learning process (Albert & Hallowel, 2013). GICAST consisted of eight units of study spread across eight weeks with study intensity of three hours per week. Each week, the course begins with a mini-game, built-in mine-craft style 2.5D visual effect. According to the researchers (Smith & Sanchez, 2010), the ability to deliver different types of information through short, interactive sessions such as mini-games could position them as a viable teaching method. The digital mini-games were particularly effective in GICAST as the adult learners were taking the upskilling course on GICAST by investing additional time and energy beyond their professional and personal commitments. The bite-sized learning helped them cope with the study workload amidst personal commitments. In addition, many educational digital games were designed with real-world context and authentic tasks (Sanchez et al., 2010). The mini-games were based on real-world context and analogy-driven scenarios that allowed the learners to anchor new and complex information delivered as part of GICAST with their prior experiences, which is crucial when working with professionals in an upskilling course (Tay et al., 2022).

Learners played the mini-game at the start of each week's study, which helped assess their current knowledge and understanding of the topics covered in the respective unit of study for the week. The game assessed the learner's current knowledge by taking the learners through a story-based narrative within the game using the in-game stealth assessment method based on previous work by Shute and Ventura (2013). Assessing participants' knowledge is difficult through a self-assessed survey, as answers may not be accurate, reliable, or devoid of bias (Shute & Ventura, 2013). The mini-games embedded as GICAST were well suited to integrating stealth assessment and other performance-based assessment methods, allowing a more reliable measure of the learner's current knowledge and skill level.

The game mechanic within the mini-games was designed to elicit intuitive responses from the learners for various real-life scenarios embedded as part of the gameplay. The intuitive responses of the learners were then compared with the baseline good security practices, and the learners were marked based on how much their responses deviated from the expected good security practices. The assumption made by the game logic is that the deviation of the learner's response from the expected good security practice was directly proportional to the gap in the learner's current knowledge and understanding. At the end of each game, the learners received feedback on their performance and were directed to one of the two learning pathways that were personalised and adapted to suit the needs of the learner.

- the green pathway was a fast-track learning route which was curated for the learners who demonstrated a good understanding of the topics covered in the week through their performance in the game,
- the amber pathway was a regular track that was curated for learners who demonstrated knowledge gaps as part of the assessment in the game.

However, the adapted learning pathways were not enforced on the learners, and they could choose the pace and sequence of their study to suit their own needs.

3.2.2 Pedagogic intent and Game Mechanics

Game-based learning resources involve the integration of education and learning processes. The key metric to measure the impact of game-based learning resource is the learning effectiveness; learner engagement and learner motivation are two key requirements for learning effectiveness. The game design methodology as discussed in the previous section considered these two key factors, in addition to other factors such as the usability of the game, which is dependent on several other game-related factors (Balakrishna, 2021). The instructional element of the game consisted of the pedagogic intent and the intended learning outcomes, while the gaming element consisted of the game mechanic chosen to suit the pedagogic intent of the game.

Story-based narratives and role-play was used across all the eight games in addition to specific game mechanics to suit the learning content. Story-based narrative and role-play attributes of game-based learning methods lend themselves naturally to security awareness training

Story-based Games allow players to experience events and scenarios through a narrative and the use of characters (avatar/role play) is known to influence behaviour and effective for skills training (Balakrishna, 2021). In addition, use of narrative creates a bond between the learner and the avatar and reinforces the learning.

4. Evaluation and Results

Theory of change was methodology used for evaluation of the impact in this project. The theory of change has been used in many contexts and there are many examples of how the approach can be used (**John Mayne,**

2015). Participatory evaluation is generally used to assess micro-level impacts that is often qualitative in nature but can also involve quantitative methods. The participants were given a questionnaire, this is optional, prior to the start of the course and again on completion of the learning. There were also weekly quizzes and intermediary knowledge checks embedded as part of the eight-week course.

There were additional incentives that should be considered, such as if the learners completed the learning within a eight weeks, the learners were given access to free cisco certification training (Cyber essentials and cyber Ops). There was also the opportunity to compare some of the findings against the previous course that didn't benefit from game-based designed learning.

The scope of the evaluation was limited to evaluating the two main outcomes, namely, increased learner engagement and positive learner experience (implied motivation to learn). The evaluation aimed to test whether the planned outcomes were achieved as intended and understand factors that contributed to the results and identify the barriers.

The evaluation questions were derived from the project's theory of change. While the details of the theory of change methodology is out of scope, what is relevant in the context of this paper is the following:

The two questions that address the evaluation of GICAST's objectives/outcomes are:

1. What role does game-based methods play in the learner experience of online learning on GICAST?
2. What aspects of the game design are most effective in engaging the target audience?

Two major outcomes selected as the focus of the evaluation activities are: learner experience and learner engagement. Other outcomes that we considered as part of the project such as career adaptability and confidence in digital learning is out of scope for this paper.

The main evaluation methods used were:

- Collection of participant information on learner demographics, job vulnerability, attitudes towards and experience of learning, use of technology, previous gaming experience, level of digital skills, knowledge of and view of cybersecurity, motivation to learn on GICAST (**pre-survey**).
- Collection of participant information on the factors that benefited (or not) their learning experience and engagement including any change to attitudes to learning, use of technology, view of cybersecurity, motivation to continue the learning journey, career adaptability (**post-survey**)
- Qualitative data was gathered through focus group discussions

4.1 Methodology and Data Collection

GICAST had access to both qualitative and quantitative data. A mixed methodology of the evaluation took place. Triangulation of the data to interpret the outputs of the data was used to see what factors of impact, good or bad could be considered. The following approach was used for data collection: Pre and post course survey; two focus groups both before and after the completion of the course; data from the Open Learn analytics- such as time spent on games, how long users were taking to complete the course; data from the quizzes

4.1.1 Participant recruitment

All data was anonymised and the surveys, focus group discussions and quizzes were all optional for participants. The recruitment of participants was achieved through the project partners stay nimble (Stay nimble, 2018) and Department for Work and Pensions(DWP) that helped reach the community of learners that the GICAST was intended for. The demography can be described as learners that did not have a degree-level qualification, employed in low-paid/low-skilled jobs and were at risk of losing their job (vulnerable) and aged between 24 to

65. To analyse the outcomes measures from the pre and post surveys, the sample was first restricted to remove participants who did not meet the programme eligibility criteria. Once ineligible responses had been removed, there were 177 pre-survey responses and 167 post-survey responses.

4.2 Key Findings

4.2.1 Learner Engagement

- 20.8% of learners enrolled to the GICAST course completed the course within the first three months of launch. This is double the percentage of learners completing the traditional badged open courses without any game-based methods. This compares well with a median value of course completions at 12.9% from an independent study done earlier (Jordan, 2015).
- Average time learners took to complete GICAST course is 27.98 days which is 4 weeks of learning, while the course was designed for study intensity of 3 hours a week spread across 8 weeks. This is in comparison to the average time learners took to complete a similar course without game-based methods was 67.98 days, which was 8 weeks. This is further substantiated by post course survey, where 68% of GICAST learners have indicated to have spent more than 3 hours a week on learning while only 38% of learners on the old course indicated to have spent more than 3 hours on learning.

The above statistics indicate, there has been increased engagement with the GICAST content and the learners have spent more time learning than learners on the old course and in comparison, to what was anticipated by the course designers.

4.2.2 Engagement with games and quizzes

Qualitative data analysis shows that games played an essential role in supporting most learners' engagement. The post-survey and focus group analysis revealed that the learners found the following aspects particularly engaging:

- *Experiential learning* - being able to take part in an action happening in a virtual scenario rather than just reading the course content:

“the weak and strong passwords showed that having different passwords in different services is more secure - the physical representation of the game, and engaging with it for me was more enlightening than simply just reading it”

[Survey respondent in reply to a question ‘Why did you like those games most?’]

- *Relevance* - a context that the learners can relate to and recognise in their own life
“The “Hidden Connections” game helps me identify some bad choices I used to make – using free WIFI, being careless with confidential information in a public place, and divulging personal information indiscriminately.”
- *Decision-making* – questions embedded in the games to elicit decisions were seen as engaging, clicking to follow the action less so:

“Most engaging were the ones where I actually had to do something with my brain rather than following the action. So quite a few of them.”

Overall, 71% of survey respondents felt that the fun element of the games helped them engage more with the course.

A minority of post-survey respondents (3.16%) did not engage in the games, and 13.29% felt they gained nothing from the games. 10 out of 84 who replied to a question:

‘Are there any games you didn’t like, if yes please tell us why’, did not find the games engaging either due to the quality of graphics or confusing storyline.

“I found their presentation “clunky” and old-fashioned”

4.2.3 Learner Experience

Learners were generally very positive about the course. 94.51% of post-survey respondents enjoyed learning on the course, 90.51% were either quite or very satisfied with their learning experience, and 84.66% agreed or strongly agreed that studying the course was fun.

The responses to the question ‘Please describe your favourite part of the course’ varied with learners appreciating the course structure, variety of content, or topics of interest. Overall, games have received the most mentions (35 out of 106), followed by quizzes (20).

These statistics as well as the data gathered on the post-course survey on the games indicate that the games played a large part in enhancing the learning experience of the learners.

- 74% of learners felt ‘Games helped me understand cyber security concepts and practices’
- 66% of learners felt ‘What I learned in the games helped my understanding of other learning resources’
- 77% of learners indicated ‘Analogy-driven scenarios helped me remember key cyber security concepts and practices’
- 71% of learners felt ‘I feel that the fun element of the games helped me engage more with the course’
- 70% of learners indicated ‘The timed activities in the games helped me focus and stay on task’

5. Conclusion

The findings indicate that the games achieved their purpose in engaging the target audience and in turn overall learning experience of the learners and motivation to complete the course. The minority of learners who did not find the game component appealing or useful could skip them with no negative consequences to their learning since the games were an additional rather than core component of the course content. What was particularly engaging about the games was the hands-on action and decision-making in familiar scenarios and elements of fun/grotesque in the stories. Game aesthetics, however, were less appealing to many and off-putting to some. This indicates that the learners come with certain preconceptions about game graphics that can negatively impact their engagement if not met. The budget and timescale of the project dictated what was possible for game aesthetics and was a known limitation to the designers. This pilot project aimed at delivering a proof of concept to study the impact of game-based learning methods on adult learners in increasing the learner engagement and learner experience. The findings suggest that gaming can play a positive role in learner engagement. Overall whether the learners liked the games or not, they remembered them, which points towards games supporting improved retention of the concepts and enhanced learner experience.

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