FRAMING GAMIFICATION IN UNDERGRADUATE CYBERSECURITY EDUCATION

Sherri Weitl-Harms

Adam Spanier

John Hastings

Matthew Rokusek

CISSE November 14, 2022

OUTLINE

- Gamification in Cyber Security Operations (CSO) Education

- Study Design

- Organizational Constructs for Gamification Applications (GA)s

- Framing Theory & Frame-Reflective Discourse Analysis

- CSO GA Frames

- Summary

GAMIFICATION IN CSO EDUCATION

- CSO Education
  - Requires comprehension of complex concepts
  - Requires high level of technical and abstract thinking

- Gamification as a practice demonstrates a notable increase in student engagement and motivation when implemented correctly

STUDY DESIGN

- **RQ1. Organizational Constructs.** What constructs exist that help identify and organize intrinsic characteristics of GAs for CSO education?

- **RQ2. Characteristics.** What characteristics naturally provide order and structure for CSO GAs?

- **RQ3. Framing.** For each CSO GA identified, within which identified frame does it fit?

RQ1: ORGANIZATIONAL CONSTRUCTS FOR GA

- Goal: Ordering GAs into groupings, similar to zoological groupings, yet careful to not "*kill innovation because new combinations cannot be boxed*" into existing groupings.

1. Study existing schematic systems
2. Identify a system useful for describing CSO GAs, and
3. Modify this system as emergent characteristics appear

ORGANIZATIONAL CONSTRUCTS: CLASSIFICATION SYSTEMS BASED ON GAME ELEMENTS

- Werbach and Hunter classified using important game dynamics: constraints, emotions, narrative, progression and relationships

- Dicheva et al., classified based on game mechanics, context of applying gamification, implementation, and evaluation

- Monteiro et al., evaluation criteria based on "engagement", "motivation", and "satisfaction".

- Toda et al. created an element-based taxonomy along five dimensions: performance, ecological, social, personal, and fictional

FRAMING THEORY & FRAME-REFLECTIVE DISCOURSE ANALYSIS

- Framing Theory:
  - Act of attributing meaning to events and phenomena
  - A way of creating order out of chaos by providing a critical analysis of the multiple, often conflicting, ways in which we perceive and discuss a concept

- Frames are
  - Definitions of the situation
  - Built in accordance with principles of organization which govern events and our subjective involvement in them

Goffman, 1974; Rein & Schon, 1996

FRAMING THEORY & FRAME-REFLECTIVE DISCOURSE ANALYSIS AS AN ORGANIZATIONAL CONSTRUCT

- Mayer, 2016:
  - For serious games, "*frame-reflective discourse analysis is a better way to dissect how to define serious games and the effect they have on the broader discussion of the issue*"
  - *Although the frames are relative, they are not irrelevant*
  - *They structure ongoing discourses about what the GA can and cannot do in terms of learning and change appears to fit more closely*

- With the objectives set forth in this research, frames provide a better organizational construct than quantitative classifications based on the summation of game mechanics/elements

CLASSIFICATION SCHEME (FRAMES) FOR GAMIFICATION IN CS EDUCATION*

Created framing construct for GAs used in Data Structures and Algorithms (DSA) education. They found:

Enhanced Examination (EE)	2
Visualization of Abstract Ideas (VAI)	4
Dynamic Gamification (DG)	0
Social and Collaborative Engagement (SCE)	2
Total DSA GAs	**8**

This research used these framing constructs as a solution to RQ1

UNDERGRADUATE CYBERSECURITY GAS

- Comprehensive study of existing gamification implementations in CSO coursework
  - Found 74 primary studies that used and evaluated GAs in undergraduate CSO education
  - A total of 80 undergraduate CSO GAs evaluated
  - https://bit.ly/3S260GS

(Harms et al., CCERP, 2022)

RQ2: CSO GA CHARACTERISTICS

- Understand GAs from characteristic-based point of view

- Due to the qualitative and emergent nature of RQ2, answer evolves as CSO GAs discovered and synthesized

- Characteristics key to formalizing the frames include:
  - Intended purpose of the GA
  - Level of engagement the student can experience with the GA
  - Level of immersion the student can experience within the GA
  - Level of control the player has to manipulate or co-design the game world
  - Level of social interaction available in the GA
  - Level of self-directedness available in the GA

RQ3: CSO GA FRAMES

After observing emergent characteristics of the CSO GAs, each GA was placed into the frame in which it best fit new frames added as new characteristics emerged

Enhanced Examination (EE)	17
Visualization of Abstract Ideas (VAI)	4
Missions and Quests (MQ)	27
Simulations(Sim)	9
Aspirational Learning (AL)	17
Dynamic Gamification (DG)	3
Social and Collaborative Engagement (SCE)	3
Total CSO GAs	80

ENHANCED EXAMINATION

- EE GAs attempt to better engage students within the context of an exam, quiz, or homework by providing a graphically attractive and/or interactive interface

- Examples:
  - Generalized education gamification frameworks such as Socrative, Kahoot!, Seppo, and OneUP
  - UltraLearn & GamifiedLearn designed to teach cybersecurity to learners with any background

VISUALIZATION OF ABSTRACT IDEAS

- Utilize visualization to describe abstract ideas that are difficult to comprehend

- Examples:
  - **Riposte,** insecure enough to be "hackable", but secure enough not to be abused; used to expose students to various security concepts
  - Zhang et al. , interactive visualization tool that aims to help students gain a deeper understanding of buffer overflow concepts
  - **hACME,** teach students software security, specifically within web applications

MISSIONS AND QUESTS

- Utilize visualization AND add a story line and well-defined step-by-step processes that enable students to complete quests as they progressively learn content

- Examples:
  - Cybersecurity virtual escape rooms
  - **CounterMeasures**, a series of guided security missions
  - **BashDungeon**, an adventure inside a dungeon, aimed at reproducing the topology of a Unix file system
  - **Temple of Treasures**, a 2D game to learn Discretionary Access Control and Mandatory Access Control, where the player is in search of gold, stuck in a temple, and needing to gain knowledge on targeted concepts to unlock the doors along the escape pathways
  - **SherLOCKED**, a 2D top-down puzzle adventure game to help students' knowledge of foundational security concepts

SIMULATIONS

- Provide environmental ambiance and context oftentimes via immersive content, into which narrative and story are integrated to bolster engagement; Players are free to move around and explore (No step-by-step process)

- Examples:
  - **QuaSim**, 3D GA that poses quantum cryptographic problems to students who interactively move around the environment to find the solutions
  - **Space Fighter**, 3D action/adventure game designed to cover phishing attack techniques as well as different types of malware
  - **Cybermatics,** allows students to "play" through an authentic scenario (case study) as a member of a professional team
  - **PenQuest**, a meta model designed to present a complete view on information system attacks and their mitigation while simultaneously providing a tool for both semantic data enrichment and security education
  - **Playground**, students create their own network security architecture, then turn around and figure out all the different ways they might crack it

ASPIRATIONAL LEARNING

- Goal driven simulations, test-beds and competitions. Different than MQ & Simulations in that no predefined step-based process is required; the student simply needs to accomplish some goal in any way possible as fast as possible

- Examples:
  - Capture the Flag competitions
  - CyberCIEGE
  - Haaukins cyber security training platform, an "*immersive, interactive learning platform, which allows students hands-on, practical experience with cyber security and ethical hacking in an online, virtualized environment*"

DYNAMIC GAMIFICATION

- GA that dynamically changes according to user input throughout its gamified life-cycle; Student-led innovations

- Examples:
  - Svabensky et al. (2018), students participate in a game-development based learning project that sees the individual creation of different penetration testing games
  - **Citadel Programming Lab,** a GitLab instance for simulated secure programming tasks and a tower defense game
  - Celeda et al. (2020), students participate in a game-development based learning project where paired students create CTF games that are deployed to the Kypoindustry industrial control systems testbed

SOCIAL AND COLLABORATIVE ENGAGEMENT

- GAs that allow students to regularly and easily interact
- Examples:
  - **PeerSpace**, a network based collaborative learning environment ; utilizes peer review, project repositories, wikis, profiles, friends, blogs and discussions to build relationships and encourage collaboration between students
  - **Classroom Live**, students and teachers work together to create an application for communicating generalized CS coursework
  - **Code Defenders**, teaches software testing in a collaborative way. Attackers create mutant versions of the program and defenders write test cases for the program being tested. As players progress through levels of the game, they incrementally learn and practice testing concepts.

RQ3: CSO GA FRAMES

Enhanced Examination (ex: Kahoot!)	17
Visualization of Abstract Ideas (ex: Riposte)	4
Missions and Quests (ex: Escape rooms)	27
Simulations (ex: QuaSim)	9
Aspirational Learning (ex: CTFs)	17
Dynamic Gamification (ex: Citadel programming lab)	3
Social and Collaborative Engagement (ex: CodeDefenders)	3
Total CSO GAs	**80**

DISCUSSION

Observed two emergent dimensions that delineate certain frames away from each other:

1) Engagement and 2) Social Interaction

- EE, VAI, MQ, Sim, and AL are generally motivated by a need to better motivate and engage students

- SCE and DG focus more on how students engage with each other

FUTURE WORK

- As the frames increase along the engagement dimension, different levels of social interactivity can be applied to them by sliding them across the social interaction dimension.

- These apparent dimensions allow combinations of social interaction frames and engagement frames (e.g. DG EE, SCE VAI, etc.) to be formulated for potentially more concise user outcomes.

SUMMARY

- **Organizational Constructs**
  - Provides a broad overview of where effort is being placed in CSO gamification development
  - Helps researchers better gauge which areas in CSO gamification need more attention

- **Framing**
  - Useful in determining the current state of the usage of GAs
  - Provides a distinction between the interpretation of what is going on while a student is using the GA, and the interpretation of the phenomena behind these experiences

THANK YOU

- Questions?

REFERENCES

- K. Werback and D. Hunter, The Gamification Toolkit. Philadelphia, PA: Wharton School Press, 2015.
- D. Dicheva, C. Dichev, G. Agre, and G. Angelova, "Gamification in education: A systematic mapping study," Educational technology & society, vol. 18, no. 3, pp. 75–88, 2015.
- R. H. B. Monteiro, S. R. B. Oliveira, and M. R. De Almeida Souza, "A standard framework for gamification evaluation in education and training of software engineering: an evaluation from a proof of concept," in IEEE Frontiers in Education Conference (FIE), Lincoln, NE, 2021, pp. 1–7.
- A. Toda, A. Klock, W. Oliveira, P. Palomino, L. Rodrigues, L. Shi, I. Bittencourt, I. Gasparini, S. Isotani, and A. Cristea, "Analysing gamification elements in educational environments using an existing gamification taxonomy," Smart Learning Environments, vol. 6, no. 1, pp. 1–14, 2019.
- I. Mayer, H. Warmelink, and Q. Zhou, "A frame-reflective discourse analysis of serious games," British Journal of Educational Technology, vol. 47, no. 2, pp. 342–357, 2016.
- E. Goffman, Frame Analysis: An Essay on the Organization of Experience. Harper & Row, 1974.
- M. Rein and D. A. Sch¨on, "Frame-critical policy analysis and frame reflective policy practice," Knowledge and Policy, vol. 9, no. 1, p. 85–104, 1996
- M. Spanier, S. K. Weitl-Harms, and J. D. Hastings, "A classification scheme for gamification in computer science education: Discovery of foundational gamification genres in data structures courses," in IEEEFrontiers in Education Conference (FIE), Lincoln, NE, 2021, pp. 1–9.
- S. K. Weitl-Harms, A. M. Spanier, J. D. Hastings, and M. Rokusek, "A systematic mapping study on gamification applications for undergraduate cybersecurity education," Proceeding on Cybersecurity Education, Research, and Practice, (CCERP) 2022.