Gamifying Course Modules for Entry Level Students

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ABSTRACT
The growing shortage of skilled professionals in cybersecurity and forensics has increased global demand for information systems professionals. To identify and attract more students to cybersecurity and forensics programs, the authors developed a game engine along with a sequence of entertaining, engaging, and educational games, suitable for forensics and cybersecurity courses. This paper focuses on the design and development of a modular educational game framework composed of a game engine and a GUI-based game creator. Following narrative and storylines of the game via interactive dialogs and visualized abstract concepts, students are motivated and engaged to obtain the necessary knowledge. Students will also develop their problem solving skills by using real tools and technologies while playing the game. The GUI-based game creator allows educators to create and develop new educational games by only focusing on game content.

CCS Concepts
• Applied Computing→Education→Interactive learning environments • Professional topics→Computing Education.

Keywords
Cybersecurity Curriculum Development; Game Design; Visualization; CS Education.

1. INTRODUCTION
The current generation of students has grown up with computer games and surrounded by digital media. In 2009 Horizon Report [18], the New Media Consortium and EDUCAUSE Leaning Initiative group identified and ranked "*using games as learning tools"* as one of the top trends affecting the practice of teaching, learning, research, and creative expression over the next five to ten years. The report also pointed that the success of game-based learning strategies owes to active participation and interaction being at the center of the experience. Over the past decade, the Game-Based Learning (GBL) approach has gained considerable traction [6, 7, 10, 11, 15, 17, 19]. James Gee, in 2003, first described the impact of game play on cognitive development [6]. Educational games aim to reinforce concepts and procedures by engaging students to learn concepts and practice techniques repeatedly through making correct choices. A good educational game connects principle and concepts with real scenarios that allow students to identify what they do not know and also demonstrate that they have grasped the concepts and can apply the knowledge into real practice. Students ultimately learn from making mistakes. When the game progresses, it engages students to integrate previous and new material to solve a realistic problem. In 2012, the authors at RIT first proposed the idea of using game-based learning and visualization techniques to engage students to learn abstract concepts and to explore forensics investigation technologies and procedures through interactive games [8, 9].

This paper introduces the design and implementation of a module-based educational game framework that incorporates real-time tools and technology to engage students in learning and build students' problem solving skills. A GUI interface has also been implemented to facilitate game creation that allows instructors (and even students) to create interactive games. Following narrative or storylines of the game via interactive dialogs, we aim to attract and keep students interested and engaged in exploring technologies and procedures.

As an example of using this framework, the authors demonstrate forensic game modules designed for *Introduction to Computer Forensics or Criminal Justice or Cybersecurity* courses. The game, along with the description and teaching materials, is defined in a module that focuses on specific learning outcomes. This game-based learning approach uses games to engage students to practice the state-of-the-art technologies and develop their problem solving skills in a real environment. Visualizations and learning resources are built into the game framework, by design, to help students to understand abstract concepts, e.g., the concepts of deleted/hidden/encrypted/over-written digital evidence in digital forensics.

The rest of this paper is organized as follows. In Section II, the authors introduce the game-based learning approach and visualization technique, as well as how to apply these technologies in our game design. The game framework design and implementation are detailed in Section III, including the development of a game creator for creating and editing games. In Section IV, the authors demonstrate a forensic game as an example as well as the feedback regarding the effectiveness of this game-based approach. The conclusion and future work are covered in Section V.

2. RELATED WORK
2.1 Game-based Learning
GBL has gained considerable traction since 2003 when James Gee described the impact of game play on cognitive development [6].

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An *educational game* is a game that has desired learning objectives and is designed to teach students specific educational contents to meet the defined learning outcomes. The GBL approach explores and uses the designed game through an interesting narrative and competitive exercises to motivate students learning according to specific designed learning objectives [17]. Prensky [12] stated in his paper that "failure opens the gate to learning," and he suggested that in game-based learning, making a mistake – or trial and error – is a primary way to learn and is considered the motivation for players to keep on trying. Studies have shown that GBL can engage students with the material and make significant improvement over those participating in learning with other educational software due to the game's feature of inductive reasoning and frequent interactions with the content [2-8].

2.2 Visualization

Visualization techniques have been widely used in education since 2000, and it has been applied to cybersecurity education during the past several years [1, 2, 4, 13, 14]. They are most effective in helping students to understand abstract concepts and protocols, identify patterns, monitor activities and follow complex procedures [13].

If used appropriately, visualization can not only communicate information clearly, but also stimulate viewer engagement and attention [4], According to 2009 Horizen report [18], visualization tools are making information more meaningful and insights more intuitive.

2.3 Utilizing GBL and Visualization in Education

The approach of combining game-based learning and visualization techniques have been used in Geoscience, computer programing, information security, and other fields [1, 7, 8, 13, 14]. The Naval Postgraduate School developed a videogame CyberCIEGE [1] that uses this approach to teach computer and network security and defense. In 2012, the authors at RIT first introduced a modular approach using game-based learning and visualization techniques to engage students to learn abstract concepts and to explore forensics investigation technologies and procedures through interactive games. [8, 9]. This game-based approach used in forensics and cybersecurity edcuation is an innovative way to help convey knowledge in cybersecurity and should serve to capture the interest of technologically-focused students who may then be more likely to pursue a career protecting our digital assets.

With the support from both National Science Foundation and RIT, over the past two years, the authors redesigned and generalized the forensic game framework to a general game framework. A GUI-based interface has also been designed and implemented to facilitate game creation. As the current generation of students has grown up with computer games and television shows, such as Crime Scene Investigation (CSI), this game framework allows educators to design and create interesting narrative and activities that will harness students' interests, and engage and encourage them to gain knowledge through repetition. Students who play the game will simultaneously develop their problem solving skills and better understand the challenges with respect to the field. We anticipate that students, the game players, will retain and apply the subject matter to the real world through these intuitive, interactive and enjoyable games in a structured environment. The game framework and creation interface can be adapted for a variety of science education programs for modern education.

3. GAME FRAMEWORK DESIGN AND IMPLEMENTATION

An educational game is a game that has desired learning objectives and is designed to teach students specific educational contents to meet the defined learning outcomes. Our game aims to develop students' problem solving capabilities through interactive play in a self-learning environment. We named our game framework *IPAR* in honor of the core digital forensics process: *Image*, *Preserve*, *Analyze*, and *Report*.

3.1 The Design Goal

Since our game engine primarily targets tool-based problem solving courses, such as courses for digital forensics or other STEM education disciplines, we designed our game to be a narrative-based detective-themed adventure game in which the player assumes the role of an investigator/detective. Working on interactive real scenario cases, the player gains insight on concepts of a given subject material by practicing and being allowed to make mistakes. The game also allows students to demonstrate their capabilities to apply the knowledge to solve a realistic problem using real technical tools that are already installed on the system.

The design goal is to make our game engaging, intuitive, interactive, extensible, and adaptive, as discussed below.

1. **Engaging**: While the main purpose of an educational game is learning, a game must be designed to inspire students' motivation and keep them interested and *engaged* in learning content and technology. For example, in a forensics educational game, the gameplay revolves around the management of evidence on a series of conspiracy boards. Evocative of those seen in detective dramas, the board serves as a visual representation of the case's progress and displays connections the player has made. New leads are discovered by examining pieces of evidence and drawing conclusions based on related questions. Files and resources necessary for completing these tasks are readily accessible to the player and are presented alongside associated pieces of evidence. Animated transitions and a simple interface keep the player engaged. After all pieces of evidence in a phase of the investigation are accounted for, the next phase begins, presenting a new set of evidence. When all phases are complete, the player is prompted to create a write-up detailing their findings to be evaluated by an instructor. The conspiracy board in a forensic game depicts the storyline and provides clues to solve a real mysterious case.
2. **Intuitive and interactive**: The game interface is simple and intuitive. Designed for problem-solving purposes, the game uses interactive dialogs as feedback, guidance, and encouragement. Based on the player's choice, the game will provide different feedback through interactive dialogs to guide the player to find clues for solutions. For certain questions, players are also required to provide a written answer to justify their choice. The written questions allow instructor to judge whether students truly understand the problem. Resourceful references and material, like tutorials and hints in a visual format or document format, are built in the game to support self-learning of concepts, procedure and technologies through questions, answers, and helpful feedback.
3. **Extensible**: The educational game is extensible to enhance the breadth and depth of existing course material with multi-level modular design. Examples for modules are Linux forensics, Windows forensics, network forensics, memory forensics, mobile forensics, etc. Each module is associated with one or

more games, like hacking, fraud, intellectual property theft, and espionage. Playing games from difficulty-level modules, students gradually gain knowledge, as the competence of the student increases. Also, the modules can be incorporated into existing courses in the curriculum without requiring any course or degree program changes and curricular approval. These modules can be replicated and adopted by other science programs. IPAR is flexible and can be used to create cases covering virtually any subject material.

4. **Adaptive**: The game uses XML to support a flexible plug-and-play structure that automatically saves game interface variables, like analysis steps, narratives, questions and answers, visualization clips and hints for each digital forensics case. Using an XML reader for the game allows dynamic changes to the case content and configuration. We developed a GUI-based game-creator to allow users/instructors to easily create games without requiring XML knowledge. Therefore, this game framework supports versatile case creation and flexible case modification, and also achieves portability of game modules.
5. **Real technical skills:** Instead of using simulation tools, our game aims to develop students' hands-on problem solving capabilities using real tools and technologies. Therefore, students are able to apply their technical skills outside the game environment. Using the game creator described in Section 3.3.2, the instructors can create games incorporating real-time tools and technologies to achieve the learning outcomes predefined by the instructor for a particular subject.

3.2 Game Framework Design

The game engine is primarily built on a Windows system to interoperate with the required and commonly used tools/technologies that are already installed on the Windows system. However, the game engine is designed to decouple from real tool installation, so that the game platform can separate from the platform on which the real tools are installed to support modules from various operating systems such as Linux, Unix and MacOS. We also developed a web-based game engine that runs the game on most modern browsers to achieve portability. In this case, the player plays the game on browsers while they run real tools installed on various platforms to answer game questions.

3.2.1 Module-based Game Framework

As mentioned earlier, the game is extensible to enhance the breadth and depth of course material with multi-level plug-and-play modular design. Modules ranging from basic to advanced levels can be plugged into this game framework. Each module associates one or more interactive case studies to allow students to acquire fundamental module-specific concepts and practice the latest technologies in a fun and real computing environment. The course modules for the game framework form a distinct unit of course materials. The examples for forensic course modules are Linux/Unix system forensics, Windows system forensics, network forensics, as well as the emerging digital forensics areas such as mobile forensics, memory forensics, malware forensics, and steganography etc. Since an educational game is a game that has desired learning objectives, before creating an educational game case study, the game creator should first define "What do we want the learners/players to learn through this game?" before defining the activities.

Each course module, as shown in Table 1 below, gives the description of the module, level of difficulty, lecture content in visualizations format and document format, and one or more case studies including the narrative, relevant evidence, questions, question responses, and investigation results.

Table 1. Design of a course module

Component	Brief Description
Overview	Description of module, prerequisite knowledge, and learning outcomes
Case Description	Narrative of the case
Level of difficulty	Recommendations for the level of difficulty for college courses
Slides and visualizations	Module content for lectures or independent learning activities, *graphical visualizations* to illustrate fundamental computer forensics concepts using imagery and animation
Images (dd or FTK imager)	Created images for the level of difficulty to be used in the forensics game.
Multiple-Choice Questions and Answers	Evidence, clues, narrative(s), possible answers, etc.—everything associated with each case Response for the answers in multiple choices
Readings	Introductory or supplementary materials required for the module
Assessment	Tools for students and instructors to measure learning and module effectiveness

3.2.2 Game Interface

Educational games often use an interesting scheme to engage players in learning activities through narrative or storylines. Problem-solving games can especially inspire motivation and spark creativity. To achieve these aspects, the interface of our game has the following components:

- **Conspiracy Board**: Since our game engine is mainly designed for problem solving, the game interface is made up of a conspiracy board in the center of the screen as shown in Figure 1. For educational purposes, gameplay usually revolves around solving of problems/clues on a series of conspiracy boards. Evocative of what have been seen in detective dramas, the board serves as a visual representation of the connections and relationships among the clues when the game progresses. Each game starts with the first question or clue. Correctly responding to a question will advance the game by uncovering any connected pieces of questions that have not yet been revealed waiting for the player to solve. As the game progresses, a web of connected pieces of clues will be revealed. Animated relationships/connections among the questions depict a visual relationship of all the evidences that engages and helps players to solve the case.
- **Types of questions**: the game engine supports for multiple choice, justification, short response, and submission questions. While multiple choice questions allow the player to select from a list of potential responses, justification questions not only require the player to explain their answer with text, but also avoid players randomly guessing answers. Short response

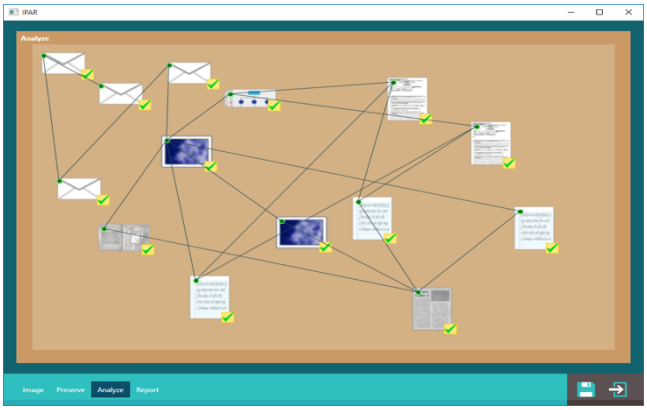

Figure 1. Conspiracy Board

questions are open-ended and require the player to write a text response. Submission questions allow players to submit screen-shots, pictures and files. Finally, messages will also be displayed on the board appearing as emails that contain narrative and procedures for players to progress. These messages will provide additional explanation of the current step and help motivate the player progresses through the steps. A GUI-based game *reader* is developed to allow instructors to view the reports submitted by students for grading.

- **Tutorials and help**: Files and resources necessary for completing these tasks are readily accessible to the player and are presented alongside associated pieces of evidence. The associated tutorials, which may include other visualizations, provide students with immediate help and feedback. Figure 2 below demonstrates a resource in a pdf format. YouTube and web links are commonly used in this game.

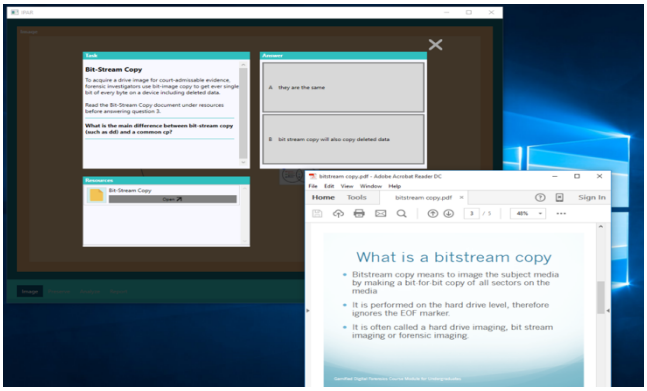

Figure 2. Open a Resource Link

- **Navigation buttons**: For simplicity, case content is organized into multiple phases and chapters. In a forensic game, four phases of the game (for IPAR is named), *Imaging*, *Preserving*, *Analyzing* and *Reporting*, are shown at the bottom of the pane. Identifying these four stages help player to reinforce the core forensics procedure and select appropriate forensics tools for each phase. Revealing and completing all questions in one phase on a conspiracy board will unlock the next board presenting a new set of challenges until they reach the last phase. Players can switch between phases in active boards by using the navigation buttons. When all phases are complete, the player is prompted to create a final write-up detailing their findings to be evaluated by an instructor. Figure 1 above shows/highlights the "analyze" phase of the game on the board.
- **Save and exit**: The system buttons that allow the player to save and exit the game are allocated on the bottom right of the screen, as shown in Figure 1. Clicking the save button will save the current progress into a single game file, replacing the case that was originally loaded from. Therefore, players can continue (resume) the game exactly from where they left off by simply loading it from this file. The exit button will return to the main menu of the game after giving the players the option to save their progress.
- **Real tools**: Different from other simulation games, this game allows students to practice their skills in a real environment using the appropriate tools that have been installed on the Windows system. For example, in a forensic game, students will gain hands-on experiences by running various forensics tools such as *EnCase* [3], *FTK* [5], *Autopsy/Sleuthkit* [16], etc.

3.3 Game Implementation

3.3.1 Platform

IPAR runs both on Windows and web browsers. The Windows version uses the Windows Presentation Foundation (WPF) and is compatible with any Windows computer running Windows 7 or newer with the .NET framework installed. To separate the game implementation and game content development, we choose XML as an information storage format to store sets of question types and other data following the pre-defined standardized structures. This design allows us to save data within self-contained files that can be moved and reread, helping achieve portability of game modules. Therefore, once the game engine is implemented and compiled, users only need to use XML to create games without modifying WPF code. The game engine builds on the .NET foundation that can not only efficiently read and write to the XML format, but also has a high level of compatibility with XML. The following figure, Figure 3, shows association between the WPF code engine code and XML files.

On the other hand, web-based IPAR was developed mainly for portability. It uses HTML/CSS, Javascript, and some PHP, and can run on any operating system by simply using any modern browser to access the website with the program. Since the program is now on the web, users no longer have to download/install any software to use it.

The web-based IPAR supports all the functionally of the original Windows program, with some added visual features such as panning, zooming, and scaling to window size. Using PHP, images and resources (PDF Files) can be stored on the server so as to reduce the file size of cases for the user.

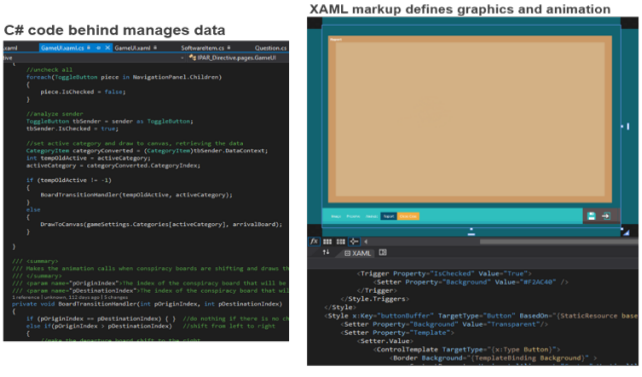

Figure 3. Game Engine and Markup Language

3.3.2 Game Creator

As we mentioned earlier, as a benefit from decoupling the engine from content, instructors only need to use XML to create games without modifying game engine implementation. To further support instructors who cannot write XML, we developed a GUI-based game creation interface to assist instructors to generate new cases by only focusing on the case content without worrying about the implementation details. Everything from content subject matter, shown in Table 1 above, to graphical elements, to storylines can be set by users to create an entertaining educational experience. As shown in Figure 4, the game creator interface allows users to create a conspiracy board with various types of questions, define, and define each question with answers, feedback and associated resources. The Game Creator will generate a XML file based on users' content inputs.

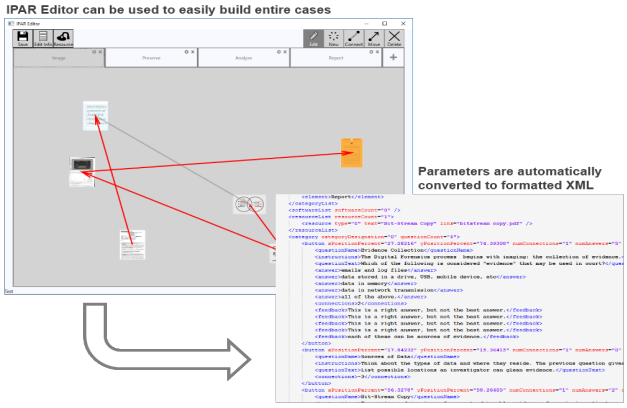

Figure 4. Game Creator Graphic User Interface

Although we started this NSF funded project to originally focus on introducing concepts of digital forensics to entry level community college students, with our current design, we believe that our game framework is flexible to support game content generated for any subject material.

4. FORENSICS GAME ASSESSMENT RESULTS

As of now, we have developed one 100-level module, *Introduction to Digital Forensics*, and five 200-level modules, *Windows Forensics*, *Windows Registry Analysis*, *Linux Forensics*, *Linux Incident Response*, and *Network Forensics*. Among which, The *Introduction to Digital Forensics* created with the game framework was piloted in a one-day faculty summer workshop for 18 college faculty. The game was also tried out at the authors' institution, and several other community colleges by about 150 freshmen in Cyber Security 101 courses.

This 100-level game is based on a storyline of investigating an academic dishonesty case. Students are required to follow the four-step digital forensics process "acquisition, *preservation*, *analysis* and *report*" to confirm or dispel the original statement of claiming one student copying another student's work. Digital forensic tools such as *FTK Imager*, *Forensics Toolkit (FTK)* and *Autopsy* are used by students to acquire a forensic-sound evidence and analyze this case. Feedback from both faculty and students were very encouraging. Majority of the players considered this game-based lab more interesting than other regular lab assignments.

4.1 Feedback from the faculty summer workshop with 18 participants

1. Indicate your degree of agreement with the following statements related to the Game Engine

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
This game was intuitive for me	0	0	0	7	11
This game was engaging for me	0	0	0	8	10
This game would probably be intuitive for students	0	0	1	12	5
The game would probably be engaging for students	0	0	0	11	7

2. Indicate your degree of agreement with the following statements regarding the hands-on activity.

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
The hands-on activity helped me to understand how the game works	0	0	0	3	15
The hands-on activity helped me to understand how the modules could be used in instruction	0	0	0	6	12
If I were given additional modules I would be able to use them	0	0	1	6	11
I could create my own modules if needed	0	1	1	7	9

3. We received all positive written comments from summer workshop. Some of the comments are given below:

- *The workshop was very interesting. I would be interested in creating modules for my more advanced classes as well as using the game for lab assignments. I think that this would be interesting to implement within my lectures and as a way to provide my online students a more step-by-step method*
- *The game was really good and informative*
- *The game seemed fun and effective - smooth enough, but not so flashy that it would detract from the purpose. I was glad that the game UI did not spend tons of time loading things, or "swooshing" through animations; a student who wants/is able to move quickly would be able to do so without behind "held back" by the game.*
- *I was glad for the opportunity to work with and learn about real tools that would be used in "serious" digital forensics. Since the programs used are free (at least for training use), I can readily continue exploring what I've learned at home.*
- *This was very well done and very worth my time. I spent as much time traveling as I did in the classroom and it was SO worth it. Well done.*
- *As soon as I can get a copy of the editor I will start building modules of my own. I can see the value in several of my classes. I would love to be able to include in an Inventory & Logistics Class I am developing now. What a great tool to teach the way to analyze inventory breakdowns.*
- *Look forward to attending more such workshops on digital forensics!*

4.2. Responses from college students

The developed forensics game was tested with 100 RIT freshmen in a Cybersecurity 101 course. Comparing this unconventional lab with other regular lab assignments, 80% students felt this game-based lab is more interesting and engaging while 20% students like the idea, but felt the trial module is not as

challenging as the regular lab since they were given too much help. With the module-based feature, we will build multi-difficulty level games in the near future to meet these students' needs. Some of the qualitative feedback received from the students is given below:

- *I thought this was more interesting than other regular lab assignments. I liked this better because while the other labs just showed us how to use the different tools, this lab showed us how to use those tools to solve a real world problem.*
- *I found this set up more interactive and informative than the normal Lab format. Yes, it makes it more enjoyable and much easier to follow instead of having a large word document with text. It also keeps me more interested in the work I am actually doing which helps me learn the information better. I like how it is easy to follow, and makes it seem more like a real world thing instead of a lab assignment in a class. I like this better than the normal labs, it's more fun, easier to understand and follow, and I feel as though I am learning just as much as a regular lab.*
- *This lab was more interactive and was a better learning experience than other labs. Due to this, I felt as though I learned more throughout the process.*
- *It was certainly interesting because of its interactivity. However, I liked the regular labs more because we needed to conduct more research for answers.*
- *I think it would have been more interesting to have less direction with the forensics lab so it would make finding evidence more open-ended.*

5. CONCLUSION AND FUTURE WORK

This paper proposed a game framework design and implementation for creating fun, entertaining, and yet educational games, in an effort to identify and attract students to cyber security programs. We believe that the use of game-based learning in a real computing environment, will be most effective in forensics and cybersecurity education that requires understanding abstract concepts and builds students' problem solving capabilities. The assessment result for the game engine and games are very positive and encouraging. The main improvement suggestion we received from students and faculty is developing more advanced and challenging games to inspire creativity. We will also explore a more open-ended iteration of games that are less directed and not bound by educational requirements.

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