

Comprehensive Report of Project “Online Facilitation of Debugging Skills through Game Based Learning” in collaboration with Commonwealth Educational Media Centre for Asia (CEMCA), New Delhi.



G4D++: A Treasure Hunt Game for Novice Programmers to Learn Debugging

Dr. Sridhar Chimalakonda

Team: Harmit, Sarthak, Akhila

Research in Intelligent Software & Human Analytics (RISHA) Lab, rishalab.in

Department of Computer Science & Engineering
Indian Institute of Technology Tirupati, India

Report Summary:

This document presents a comprehensive report on the development of G4D++ game for debugging and its deployment, corresponding to each of the deliverables. G4D++ is a multi-level game supporting multiple avatars to facilitate learning of debugging skills with deployment at Indian Institute of Technology Tirupati (IIT Tirupati)¹ and Rajiv Gandhi University of Knowledge Technologies (RGUKT)².

The game has been evaluated with a total of 108 undergraduate students, through three field deployment studies. 70 students from RGUKT and 38 students from IIT Tirupati have participated in the evaluation that involved a user survey based on a questionnaire derived from the Model for the Evaluation of Educational Games (MEEGA+) evaluation model³. The results of the survey reveal a quality score of 64% and 81% at RGUKT and IIT Tirupati respectively, indicating that the game has reasonably good quality, according to the MEEGA+ evaluation model.



Deployment at IIT Tirupati



Deployment at RGUKT

The rest of the document has sections corresponding to each of the deliverables as per the project plan. In addition to this document, we share the deliverables [folder](#) with the following documents:

1. Deliverables Folder (individual files for each deliverable)
2. Game Executables Folder (Both Windows and Linux versions for download)
3. Material
 - 3.1. Project Summary Slide Deck
 - 3.2. G4D++ Game Overview Document used during Deployment

¹ The Indian Institute of Technology Tirupati (IIT Tirupati), established in 2015, is an autonomous Institute under the Ministry of Education, Government of India. It is declared as an Institute of National Importance under the Act of Parliament of India (Institutes of Technology Act, 1961), <https://www.iittp.ac.in/>

² Rajiv Gandhi University of Knowledge Technologies (RGUKT) has been setup by the Government of Andhra Pradesh (AP), India as a hub of four IIITs with the primary objective of providing high quality educational opportunities for top 1% of the rural students of AP from low-income and underrepresented group with students. The student group specifically represents diverse, ethnic and underserved groups based on reservation, income, gender and so on across all districts in the state of AP.

³ Petri, G., von Wangenheim, C. G., & Borgatto, A. F. (2016). Meega+: An evolution of a model for the evaluation of educational games. *INCoD/GQS*, 3, 1–40.

- 3.3. G4D++ Game Instructions
- 3.4. G4D++ Game Video
- 3.5. RGUKT_G4D++Survey Screenshots
- 3.6. Survey Form (Questionnaire)
4. Deployment Photos (RGUKT and IIT Tirupati)
5. Appendix

S.no	Deliverables	Status
3.1	Game Requirements and Design Document	Completed
3.2	Design and Development of Game	Completed
3.3	Deployment at IIT Tirupati and Evaluation report	Completed
3.4	Deployment at RGUKT and Evaluation report	Completed
3.5	Comprehensive Report	Completed

Introduction and Motivation

Computing education, specifically *programming*, is considered as one of the necessary and pervasive skills for industrial jobs today owing to its wide usage across all disciplines and domains⁴. On the other hand, software often has bugs/issues and detecting, analyzing and resolving them requires immense effort⁵, making *debugging* an important and fundamental skill in computing curriculum⁶. It is also regarded as a skill that is challenging to learn and teach⁷. Even in recent times, despite the massive availability of open educational resources (OERs) and tutorials available for *debugging*, it is a difficult skill to learn for many novice programmers and students due to the passive nature of existing modes of teaching. It is here, this project aims to leverage the potential of games to foster interactivity and interest towards teaching debugging skills in open education.

Deliverable: 3.1 Game Requirements and Design Document

- To extend G4D⁸ game to create a *multi-level, treasure-hunt* based game to facilitate learning of debugging skills in higher and open education. This goal is within the purview of promoting quality learning opportunities in higher and open education and is inline with the strategic plan of COL-CEMCA⁹.

⁴ Coding - the 21st century skill, <https://bit.ly/3rFYpAi>

⁵ Chiu, C.-F., & Huang, H.-Y. (2015). Guided debugging practices of game based programming for novice programmers. *International Journal of Information and Education Technology*, 5 (5), 343.

⁶ Beller, M., Spruit, N., Spinellis, D., & Zaidman, A. (2018). On the dichotomy of debugging behavior among programmers. In 2018 IEEE/ACM 40th International Conference on Software Engineering (ICSE) (pp. 572–583).

⁷ McCauley, R., Fitzgerald, S., Lewandowski, G., Murphy, L., Simon, B., Thomas, L., & Zander, C. (2008). Debugging: a review of the literature from an educational perspective. *Computer Science Education*, 18 (2), 67–92.

⁸ A brief video demo of the game is available at <https://youtu.be/rtd2973l-TA>

⁹ Pages: 6-8, https://www.cemca.org/ckfinder/userfiles/files/Lr-Strategic%20Plan_2015-2021_01-03-2017.pdf

- A multi-level game focusing on debugging concepts in a generally acceptable programming course in computing curriculum.
- To address the varying difficulty levels of learners and backgrounds (For example, Easy, Medium, Hard), the game has to be customized for learners/players. The proposed game would achieve this by providing options to show different code snippets and errors for different levels of difficulties. This allows learners to play the game and learn debugging skills in a step-by-step manner based on their backgrounds and learning goals through multiple levels in the game. In addition, we plan to provide avatars for players as a way to improve their confidence and motivation.
- Primarily targeted for higher education, specifically first or second year college students (after Class 12). However, the game could be used by anyone with minimal background in programming either in self-learning mode or as a support to their course work.
- The game would track time being taken by the player, to prompt them directions when necessary, especially for the first timers, who are new to the game

Summary of the game with learning outcomes: G4D++ aims to teach debugging to novice programmers through a treasure hunt based game. The steps involved in the process of debugging are scaffolded by the steps involved in finding clues and finally arranging all the clues found. As the player progresses through multiple levels of the game, the player would be able to achieve the below learning outcomes:

- The learner will be able to identify possible points of infection in syntactically faulty code snippets written in C programming language.
- The learner can isolate the defective chain in the syntactically faulty code snippets written in C programming language.
- The learner can predict corrections to be made to debug the syntactically faulty code snippets written in C programming language.

Storyline of the game:

- The protagonist of the game is an astronaut whose spaceship crashes on an alien planet.
- As a result, various parts of the spaceship and the parts used to repair certain parts of the spaceship are scattered all around the planet.
- The protagonist has to find these missing parts and repair the spaceship accordingly to fly back to the home planet.
- A faulty code snippet, analogous to the broken spaceship is presented to the player, which is to be debugged and solved based on the clues found in the game.
- These clues correspond to programming constructs that could be useful to solve the faulty code snippet.
- The clues are analogous missing parts of the spaceship, which are hidden in specific elements on the planet (Figure 1). The player moves around the alien planet (Figure 2) and collects the clues accordingly (Figure 3).
- Once all the clues pertaining to a level are collected, the player goes back to the location of the broken spaceship, to debug the code snippet displayed at the broken spaceship, based on these clues. The clues collected in the level are displayed on the clue board, adjacent to the faulty code snippet, to enable mapping the clues to the defect positions in the code (Figure 4).

- Once all the clues are collected and mapping is correctly done, the player clears the specific level. The player can then move to the next level with the help of a key and door that navigates to the next level (Figure 5).
- Once the level is complete, corresponding score is displayed to the player (Figure 6)



Figure 1: Boxes containing clues for debugging



Figure 2: Finding clues in the alien city



Figure 3: Clue displayed on breaking the box

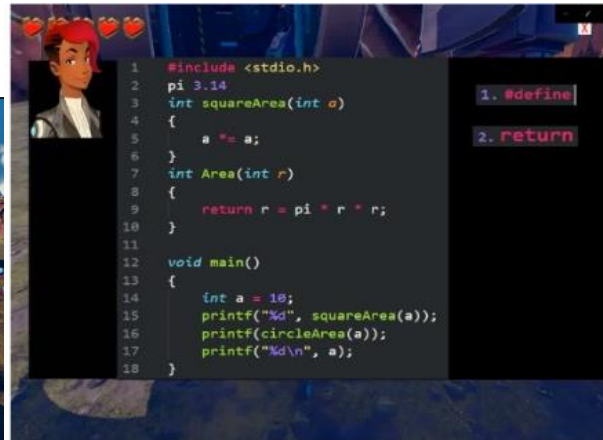


Figure 4: Faulty code snippet with collected clues



Figure 5: Alien city door & key to open it (next level)

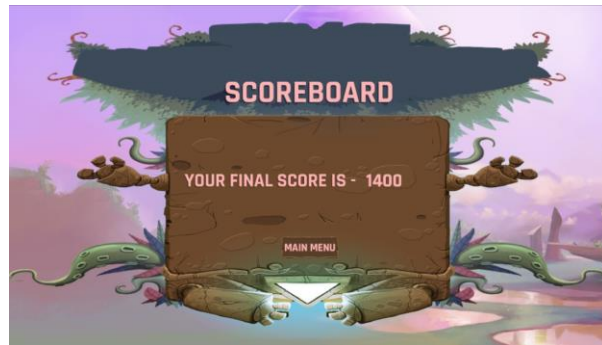


Figure 6: Score displayed on completion of game

Extension of G4D game (G4D++):

- The extended version of the game includes multiple code snippets that are dynamically displayed to the player, with dynamic clue positions, to avoid cases where players remember the location of the clues and the mapping to the faulty code snippet.
- The maximum number of clues collected could be more than the number of defect positions in the code, with the player having to select the appropriate ones, based on the level chosen by the player.
- The players can choose from multiple protagonist avatars, thus facilitating customization of the avatar. The game includes multiple levels, with increasing complexity of the faulty code snippet.
- Each level enables the player to repair a specific part of the spaceship, analogous to debugging the faulty code snippets.
- As the levels increase, the number of faulty code snippets or the size of faulty code snippets to be debugged, or the number of defect points in the faulty code snippets are increased to increase the complexity of the game.
- When the player reaches the last level, and fixes the faulty code snippets in the last level, the spaceship is completely repaired and the player can fly back to the home planet.

The G4D++ game has been designed based on these requirements and also considering the steps involved in debugging. The design and development of G4D++ are presented in Deliverable 3.2 below.

Deliverable: 3.2 Design and Development of Game

- Scaffolding debugging concepts through the game plays a major role in the design of G4D++. G4D++ has been designed to incorporate the steps involved in debugging.

Debugging involves seven steps according to Andreas Zeller, which are listed as follows:

- Step 1: Track problem in database
- Step 2: Reproduce Failure
- Step 3: Automate
- Step 4: Find possible infection origin
- Step 5: Focus on most likely origin
- Step 6: Isolate infection chain
- Step 7: Correct Defect

Debugging starts from Step 4 for novice developers, as the first three are generally logged by testing teams and other users, in organizations that involve real-time developers. Hence, G4D++ has been designed to incorporate debugging steps from Step 4 to Step 7.

- Step 4: Find possible infection origin → Selection of appropriate line to fill obtain clues
- Step 5: Focus on most likely origin → Identification of appropriate position in the line selected in the previous step
- Step 6: Isolate infection chain → Points awarded to players to users for locating appropriate position for each clue to motivate players towards infection isolation

- Step 7: Correct Defect → Locate appropriate positions for all clues and consequently correct the defect.
- Another important aspect to be considered while designing G4D++ was to ensure that the scaffolding does not further induce cognitive load on the players, while learning debugging. The idea of divide and conquer, to reduce cognitive load has thus been followed in designing G4D++. Here, we presented clues to the players that are to be filled in the faulty code snippet, analogous to dividing the problem into multiple statements and solving each one of them.
- As an extension to G4D, we designed upto three levels in the game. Each level has been designed to increase the complexity gradually.
- In the first level (or the easy level), the players are displayed with clues, which are to be filled, using drag-and-drop feature, in the faulty code snippet. The clues are hidden in the boxes in the game, with the majority of the boxes consisting of clues. The number of clues found by the player are equal to the number of possible faulty positions in the faulty code snippets. Thus, each of the clues found will be mapped to one and only one position in the faulty code snippet.

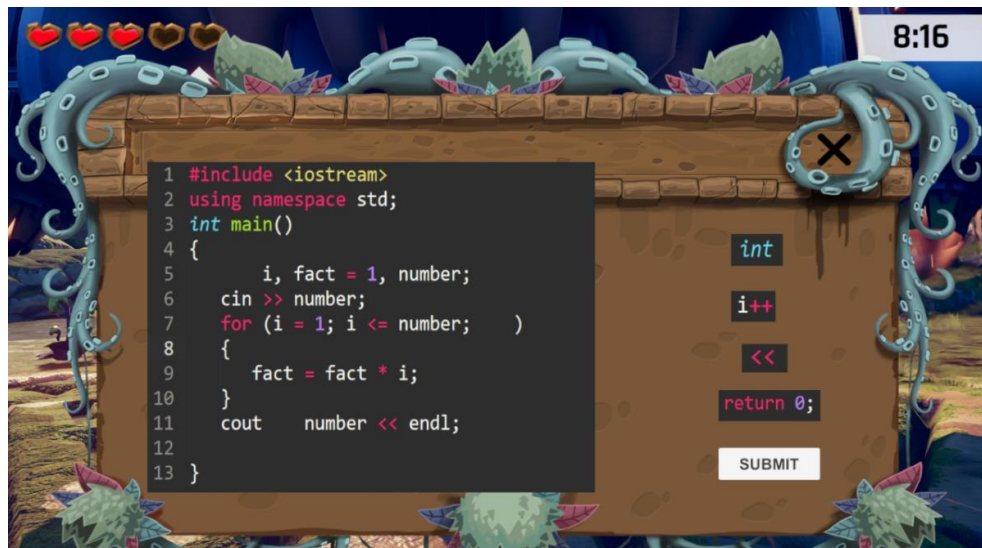


Figure: Drag and drop feature in easy state

- In the second level (or the medium level), the players are required to fill in clues in faulty code snippets by typing in the clues. Further, the number of boxes containing the clues is lesser than those in the first level. The player collects more clues than the faulty positions in the faulty code snippets, but only a few clues of the collected ones fit into the faulty code snippet. As a result, the player can match only some of the collected clues to the faulty positions in the faulty code snippets, thus, increasing the complexity of the game in the next level. Penalty points are given to the player in case of an incorrect match, thus requiring the player to be confident about the possible position for each clue.
- In the third level (or the hard level), the player finds clues in the boxes, with a minimal number of boxes containing the clues. But, in this level, the clues cannot be directly filled

into the faulty positions. The clues are presented in the form of a puzzle in this level, requiring the player to solve or decode the puzzle before arriving at the actual clue. The player has to fill in (type in) the actual clue into the faulty position. This level thus increases the complexity further, by requiring the player to solve the puzzle and arrive at an appropriate clue that fits the faulty position in the faulty code snippet.

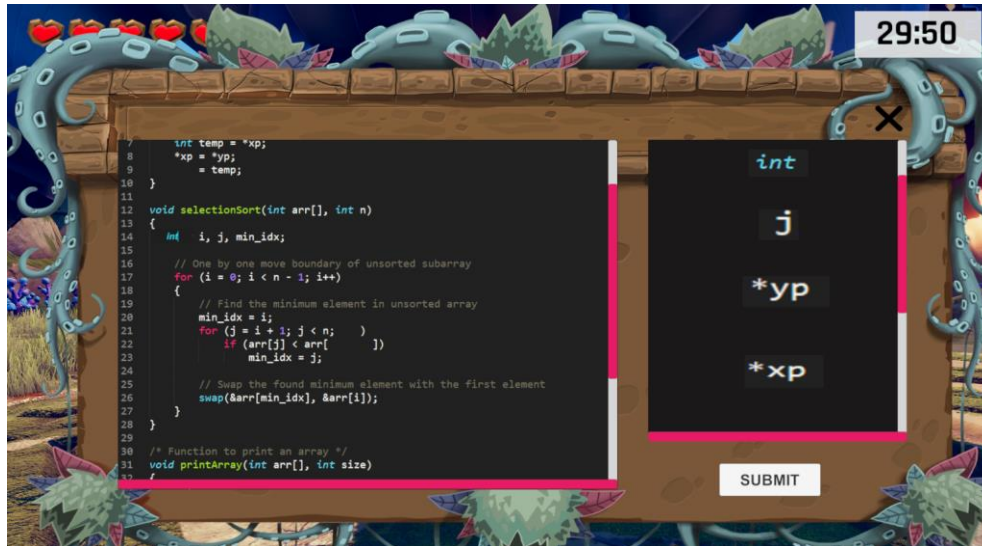


Figure: Typing the correct clues in medium and hard states

Each level also varies with the number of faulty code snippets that are to be solved to clear the level, with an increasing number of faulty code snippets from easy to hard levels.

G4D++ has been further designed to track the player activity and guide the player in finding clues in case of inactivity or frequent incorrect attempts.



Figure: Game being paused of inactivity for long case

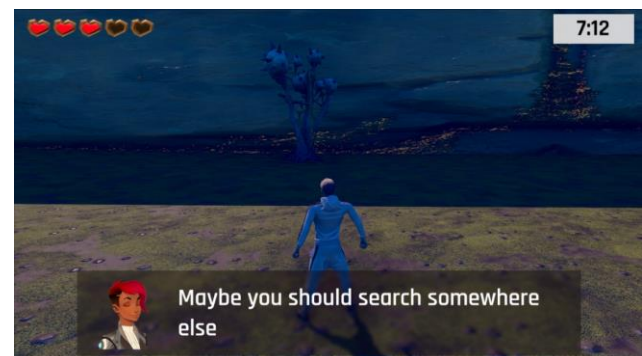
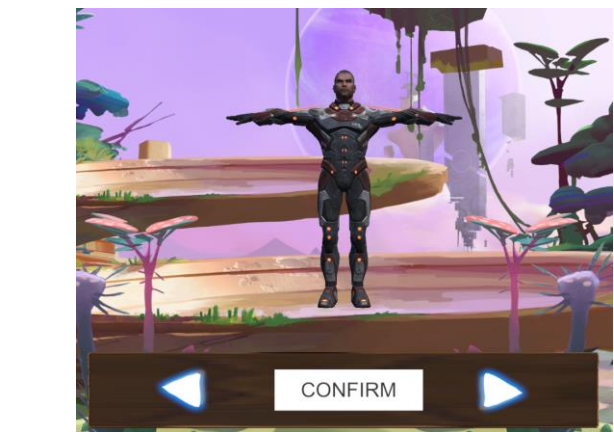
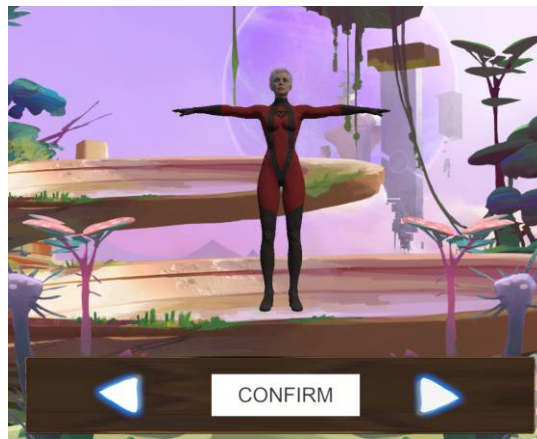
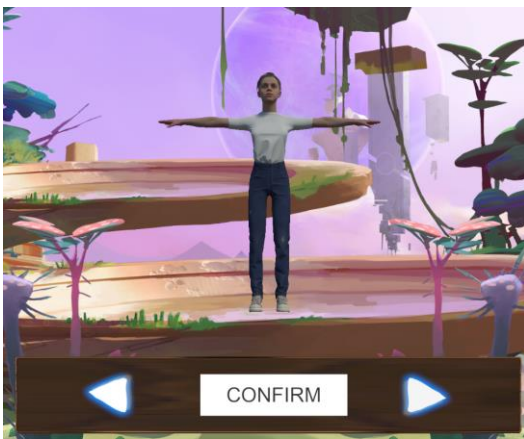
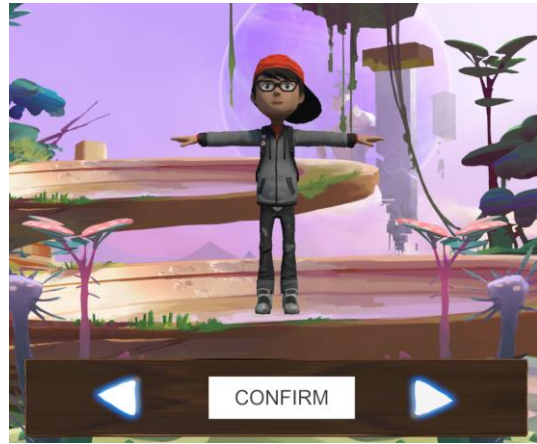


Figure: Message to guide the player to the clues in of multiple wrong directions

- Players are also provided with options to choose among six avatars to include a diverse audience, as shown below.



Unity 3D has been used to develop G4D++. The 3D Kit provided by Unity 3D has been used to define player features, model actions of the player, import structures, layouts and functionalities of these structures. Scripts to define controls of each object in the game such as player, alien enemy animal and other structures have been written in CSharp programming language. Faulty Code snippets, with their corresponding correct code snippets, written in C/C++ language are defined. Clue sets required to debug these code snippets are also defined.

Clue sets that can help in debugging the code snippets, faulty code snippets to be debugged and correct code snippets are then uploaded onto the database. Functionalities and structures imported from 3D Kit and Scripts written in CSharp programming language are then uploaded to the database. Each structure is associated with predefined actions that can be performed. Each structure-action pair in the game is also associated with corresponding control features inside the database. Each faulty code snippet is associated with a clue set that is useful in debugging the snippet. This pair of faulty code snippet and clue set are then linked with the correct code snippet in the database. The camera angle and direction, and the light direction are defined with the help of Unity 3D. Unity 3D helps in integrating the scripts containing controls, written in CSharp programming language, with defined structures and actions.

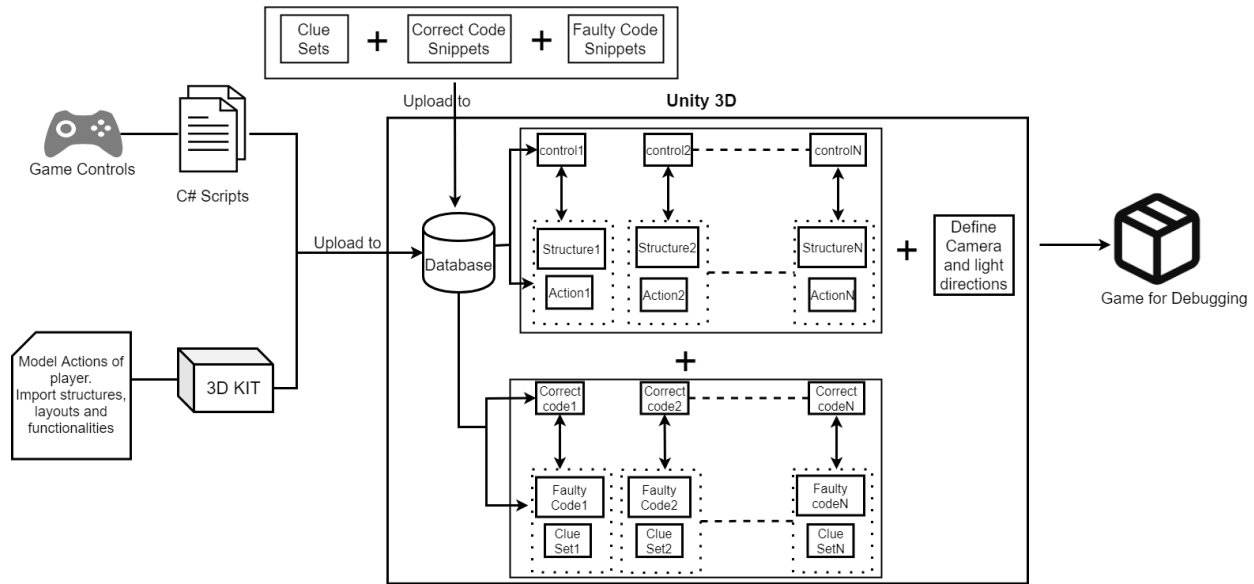


Figure : Development Approach of G4D++

To understand the usefulness of G4D++ towards debugging and also to identify possible glitches or overlooked aspects that would make it difficult for the player to play the game, we performed a preliminary evaluation with 8 students at IIT Tirupati. Based on the suggestions and feedback obtained through this preliminary study, we improved the game and deployed it at IIT Tirupati and performed an extended evaluation. The details of the preliminary evaluation and extended deployment study are presented in Deliverable 3.3 below.

Deliverable: 3.3 Deployment at IIT Tirupati and Evaluation report (Prototype Version for Design Iteration)

About IIT Tirupati - The Indian Institute of Technology Tirupati (IIT Tirupati), established in 2015, is an autonomous Institute under Ministry of Education, Government of India. It is declared as an Institute of National Importance under the Act of Parliament of India (Institutes of Technology Act, 1961). The IIT system has 23 Institutions of Technology, which are well known both nationally and internationally for excellence in education and research in engineering and science. IIT Tirupati has a student strength of ~1200+ across all its undergraduate and graduate programs in multiple disciplines.

Before the field deployment of the proposed game, it is critical to understand and improve the game design and features through an initial prototype evaluation.

G4D++ has been developed as a treasure hunt based 3D game, with an aim to support and motivate users to learn and practice debugging of code snippets. Hence, our primary goal is to assess its usability, correctness and player experience. We follow the commonly used MEEGA+ model and a 5-point Likert scale to evaluate G4D++, as it includes the factors of player experience and usability. The MEEGA+ model involves decomposing evaluation goals into measures and instruments to evaluate the perceived quality of educational games in terms of player experience and perceived learning. The instruments themselves involve a standard questionnaire for multiple dimensions related to evaluation of educational games¹⁰.

Demographics of participants:

Gender	
Male	8
Female	0
Age (in years)	
18	1
19	6
20	1
Prior Programming Experience	
0-1	2
1-2	2
2-3	4
How often do you play games?	
Very Often	4
Often	2
Neutral	3
Sometimes	0
Never	0

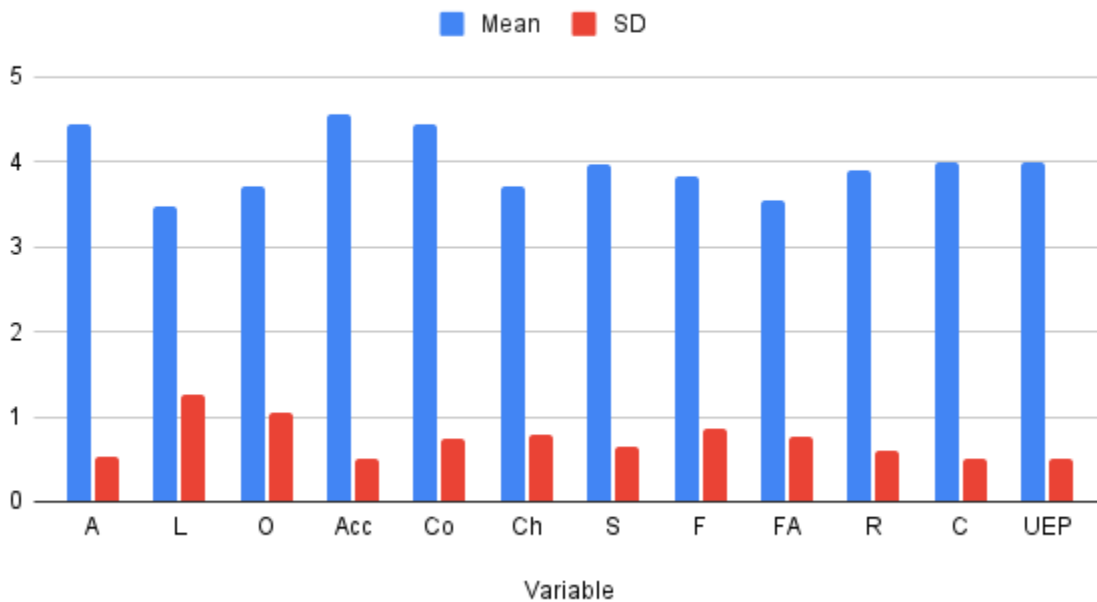
Variables used to evaluate G4D++ and respective Mean and Standard Deviation:

¹⁰ <http://www.gqs.ufsc.br/meega-a-model-for-evaluating-educational-games>

		Mean	SD
A	Aesthetics	4.44	0.53
L	Learnability	3.48	1.26
O	Operability	3.72	1.05
Acc	Accessibility	4.55	0.51
Co	Confidence	4.44	0.73
Ch	Challenge	3.712	0.79
S	Satisfaction	3.96	0.64
F	Fun	3.83	0.86
FA	Focused Attention	3.55	0.76
R	Relevance	3.89	0.6
C	Correctness	4	0.5
UEP	User Error Protection	4	0.5

Distribution of Mean and Standard Deviation across the MEEGA+ variables:

Mean and SD



Detailed Questionnaire to evaluate G4D++ and the results of evaluation:

Variable	Questions	Mean	SD
A	The game design is attractive (interface, graphics, cards, boards, etc.).	4.44	0.53
L	I needed to learn a few things before I could play the game.	2.78	1.56
L	Learning to play this game was easy for me.	3.89	0.93
L	I think that most people would learn to play this game very quickly.	3.78	1.3
O	I think that the game is easy to play.	4.11	0.6
O	The game rules are clear and easy to understand.	3.33	1.5
Acc	The game provides enough flexibility to play the game as per my choices (multiple avatars and difficulty level choices)	4.44	0.53
Acc	The fonts (size and style) used in the game for code snippets are easy to read.	4.67	0.5
Co	When I first looked at the game, I had the impression that it would be easy for me.	4.44	0.73
Ch	This game is appropriately challenging for me.	3.78	0.67
Ch	The game provides new challenges (offers new obstacles, situations or variations) at an appropriate pace.	4.11	0.6
Ch	The game does not become monotonous as it progresses (repetitive or boring tasks).	3.33	0.87
Ch	The game promotes competition amongst the players	3.56	0.88
Ch	The game motivated me to perform better in the tasks and complete the game in the best possible time.	3.78	0.97
S	Completing the game tasks gave me a satisfying feeling of accomplishment.	4	0.5
S	It is due to my personal effort that I managed to advance in the game.	3.78	0.67
S	The game contributed to my learning	3.89	0.6
S	I feel satisfied with the things that I learned from the game.	3.89	0.78
S	I would recommend this game to my colleagues.	4.22	0.67
F	I had fun with the game.	4.11	0.6
F	Something happened during the game (game elements, competition, etc.) which made me smile.	3.56	1.13
FA	There was something interesting at the beginning of the game that captured my attention.	4.11	0.33

FA	I was so involved in my gaming task that I lost track of time.	3.22	0.97
FA	I forgot about my immediate surroundings while playing this game.	3.33	1
R	The game contents are relevant to my interests.	3.89	0.6
C	The clues given in the game are correct with respect to the code snippet provided	4	0.5
UEP	Each of the levels has a different and well-structured gameplay	4	0.5

According to MEEGA+, values of 3.5+ usually indicate positive response from the participants. Suggestions:

<p><i>Rules or like how to play the game basic instruction is necessary.</i></p> <p><i>Example: The objective of the game, what happens when you clear the monsters and about different types of chest's etc.</i></p> <p><i>"sprint" feature is helpful in exploring and in defeating the monsters since the monster's are a bit on tougher side if you can't avoid their attacks.</i></p> <p><i>The game was fun.</i></p>
<p><i>You can add some more monsters, so that exploring the map become interesting. And add hint in between the game, bcz some player telling that it's difficult to find clues..... But it's fine for me.</i></p>
<p><i>Just add some more instructions</i></p>
<p><i>Having a rules page.</i></p> <p><i>A small map to navigate the area.</i></p>
<p><i>Game graphics are good but can be more attractive and the code snippets is a good thing by which we can learn as well from this game.</i></p> <p><i>Game characters can be chosen based upon the levels .</i></p>
<p><i>1. Unable to see mouse pointer when game is paused.</i></p> <p><i>2. While standing near the door of spaceship, code snippet appears. After filling it, I was unable to move. Only after pressing Esc twice, was able to move away from the door.</i></p>

This preliminary evaluation has helped us to understand some common concerns of students as well as improving the current version for final evaluation.

Based on the feedback received through preliminary evaluation at IIT Tirupati, the game has been further improved and deployed at IIT Tirupati.

Deployment and Evaluation of G4D++ at IIT Tirupati

G4D++ has been deployed at IIT Tirupati and has been evaluated with 30 students through a physical meeting. We ensured that all the participants had basic knowledge about the syntax of C++ language. All the participants were in the second year of their undergraduate course during the survey. All the participants were explained about the game and its controls. The game has been deployed in 5 machines, which were made available during the survey. The participants were then invited in turns, with 5 participants in each

turn. The participants were then requested to play the game and solve the in-game faulty code snippets using the clues and explore various other features of the game. All the participants were given 30 minutes of timespan to interact with the game. If any of the participants lost the game during these 30 minutes, they were allowed to restart the game. The participants were then requested to fill the user survey to understand the usefulness of the game and to obtain their feedback on the game. Some of the snapshots taken during the deployment are presented below, where participants can be seen interacting with the game.



Demographics of participants:

Gender	
Male	27
Female	3
Age (in years)	
18	4
19	20
20	5
21	1
Prior Programming Experience	
0-1	20
1-2	4
>2	6
How often do you play games?	
Very Often	0
Often	8
Neutral	10
Sometimes	5
Never	7

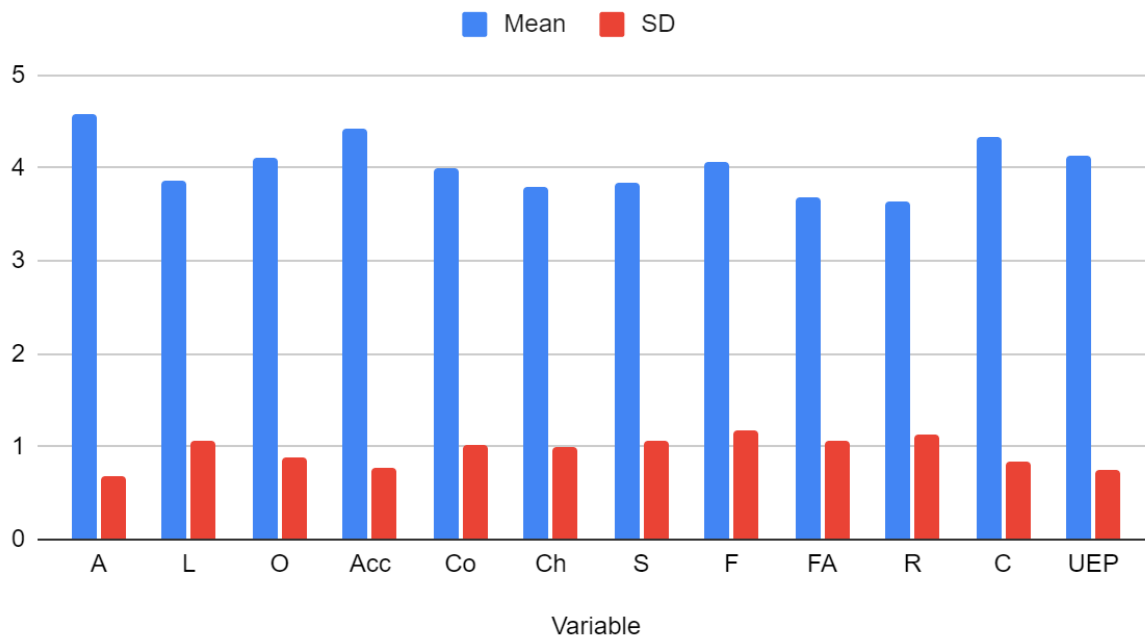
Variables used to evaluate G4D++ and respective Mean and Standard Deviation:

		Mean	SD
A	Aesthetics	4.57	0.68
L	Learnability	3.86	1.05
O	Operability	4.12	0.895
Acc	Accessibility	4.42	0.78
Co	Confidence	4	1.02
Ch	Challenge	3.796	1.006
S	Satisfaction	3.845	1.06
F	Fun	4.07	1.175

FA	Focused Attention	3.68	1.073
R	Relevance	3.64	1.13
C	Correctness	4.34	0.85
UEP	User Error Protection	4.14	0.74

Distribution of Mean and Standard Deviation across the MEEGA+ variables:

Mean and SD



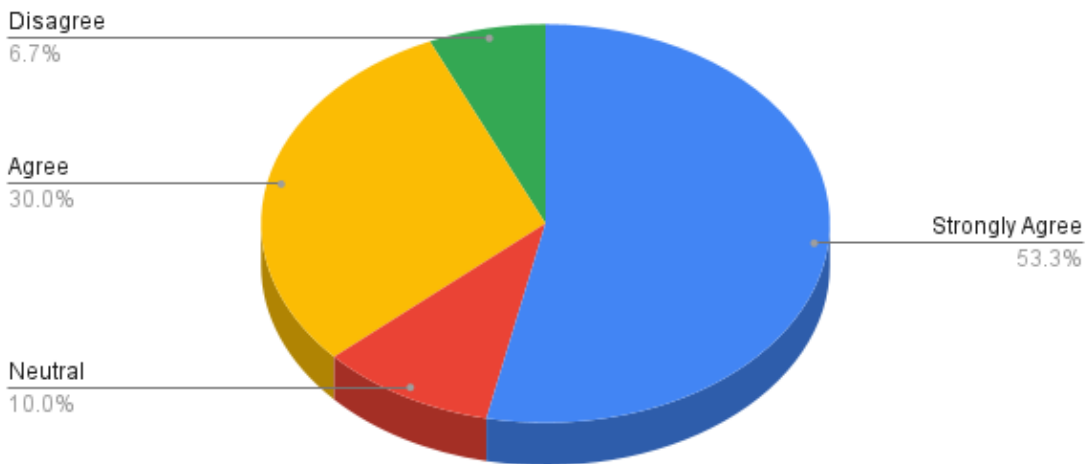
Detailed Questionnaire to evaluate G4D++ and the results of evaluation:

Variable	Questions	Mean	SD
A	The game design is attractive (interface, graphics, cards, boards, etc.).	4.57	0.68
L	I needed to learn a few things before I could play the game.	2.64	1.52
L	Learning to play this game was easy for me.	4.47	0.82
L	I think that most people would learn to play this game very quickly.	4.47	0.82
O	I think that the game is easy to play.	3.94	0.91

O	The game rules are clear and easy to understand.	4.3	0.88
Acc	The fonts (size and style) used in the game for code snippets are easy to read.	4.7	0.66
Acc	The game provides enough flexibility to play the game as per my choices (multiple avatars and difficulty level choices)	4.14	0.9
Co	When I first looked at the game, I had the impression that it would be easy for me.	4	1.02
Ch	This game is appropriately challenging for me.	3.57	1.05
Ch	The game provides new challenges (offers new obstacles, situations or variations) at an appropriate pace.	3.87	1.01
Ch	The game does not become monotonous as it progresses (repetitive or boring tasks).	3.67	1.03
Ch	The game promotes competition amongst the players	3.7	1.06
Ch	The game motivated me to perform better in the tasks and complete the game in the best possible time.	4.17	0.88
S	It is due to my personal effort that I managed to advance in the game.	3.6	0.97
S	The game contributed to my learning	3.74	1.23
S	I feel satisfied with the things that I learned from the game.	3.74	1.12
S	I would recommend this game to my colleagues.	4.3	0.92
F	I had fun with the game.	4.3	1.06
F	Something happened during the game (game elements, competition, etc.) which made me smile.	3.84	1.29
FA	There was something interesting at the beginning of the game that captured my attention.	3.97	1
FA	I was so involved in my gaming task that I lost track of time.	3.57	1.08
FA	I forgot about my immediate surroundings while playing this game.	3.5	1.14
R	The game contents are relevant to my interests.	3.64	1.13
C	The clues given in the game are correct with respect to the code snippet provided	4.34	0.85
UEP	Each of the levels has a different and well-structured gameplay	4.14	0.74
Ch	The game promotes competition amongst the players	3.7	1.06

According to MEEGA+, values of 3.5+ usually indicate positive response from the participants. Also, the quality score calculated based on the mean values of the variables and the cronbach alpha values defined by MEEGA+ result in the quality score of 81%. According to MEEGA+, games with quality score value less than 42.5 are considered to be of low quality, between 42.5 to 65 are considered to be of good quality and those with value greater than 65 are considered to be of excellent quality. Thus, we observe that, based on the survey results, G4D++ has an excellent quality level.

I would recommend this game to my colleagues.



A sample question and distribution of the participant response

Suggestions:

<i>It would be better if the graphics and everything changes according to levels, like right now i find the same graphics, colors etc. for every level</i>
<i>If possible maybe you can decrease the life of character each time it falls from a huge height.</i>
<i>remove the timer countdown</i>
<i>add map</i>
<i>allow camera to zoom in and pan out</i>
<i>fix bug related to ground on top of hill</i>
<i>There is a huge disconnect between programming and the game. If it was a programming related game then the programming part should have been throughout the game rather than just at the end. Graphics, animation and controls are amazing. What seems missing is the motive and it's execution.</i>
<i>For some improvements in the game - there could be a small icon on the screen which could contain how many clues are collected and how many are not and also what are the clues that are collected.</i>

<i>Have a sensitivity control over the motion of the character</i>
<i>Game dont contain much debugging, the debugging can be increased, Map can be added</i>
<i>Forming a link between killing the aliens and debugging the code might just help, these 2 things don't seem connected at all.</i>
<i>The time for each basic level can be increased upto 25min .Because it takes time to first time learners of this game to know about this game</i>
<i>Some glitches were there like jumps were not perfect and the camera movement is a bit laggy</i>
<i>It is a great game accompanied with great graphics and has a gameplay which keeps the player involved in this game.</i>
<i>The overall game is superb Had a good experience with it</i>

The game was later deployed at RGUKT, for a large-scale evaluation, the details of which are reported in the Deliverable 3.4 below.

Deliverable: 3.4 Deployment at RGUKT and Evaluation report

About RGUKT: - Rajiv Gandhi University of Knowledge Technologies (RGUKT) is a hub of four IITs setup by the Government of Andhra Pradesh (AP), India. The primary objective of RGUKT is to provide high quality educational opportunities for top 1% of the rural students of AP from low-income and underrepresented groups by admitting them for 6-year integrated programmes at the age of 15. Every year, RGUKT admits ~6,000 students and has around ~24,000 students on their campuses. IIT Tirupati has an MoU with RGUKT to mentor and support RGUKT for excellence in teaching and research. The key admission criteria at RGUKT is that the student should hail from a low income and rural family. They often come from diverse, ethnic and underserved groups based on reservation, income, gender and so on across all districts in the state of AP. Specifically, 21% of students belong to SC, ST; 29% in BC and economically weak population, with 33% reservation for girl children¹¹.

G4D++ has been deployed at RGUKT and has been evaluated with 70 students through an online zoom meeting, but the game was physically played by the students in the computer labs of RGUKT. We ensured that all the participants had basic knowledge about the syntax of C++ language. All the participants were in the third year of their undergraduate course and agreed to have basic knowledge of object oriented programming concepts and the syntax of C++ language during the survey. All the participants were explained about the game and its controls. An email consisting of the installation instructions to install the game on their local machines has been sent to all the participants. The game was also deployed in the machines in the laboratory of RGUKT for better access to the students. A brief explanation of the game, its controls and features have also been sent along with the email. The participants were requested to install the game on their local machines prior to joining the meeting. The participants were explained about the

¹¹ <https://www.rgukt.in/pdfdoc/RGUKT-Admission2020-Prospectus.pdf>

game and its controls at the beginning of the meeting and were then requested to play the game and solve the in-game faulty code snippets using the clues and explore various other features of the game. All the participants were given 60 minutes of timespan to interact with the game. If any of the participants lost the game during these 60 minutes, they were encouraged and allowed to restart the game. The participants were then requested to fill the user survey to understand the usefulness of the game and to obtain their feedback on the game.

Some of the snapshots taken during the field deployment are presented below, where participants can be seen interacting with the game.



Demographics of participants:

Gender	
Male	25
Female	45
Age (in years)	
19	27
20	39
21	4
Prior Programming Experience	

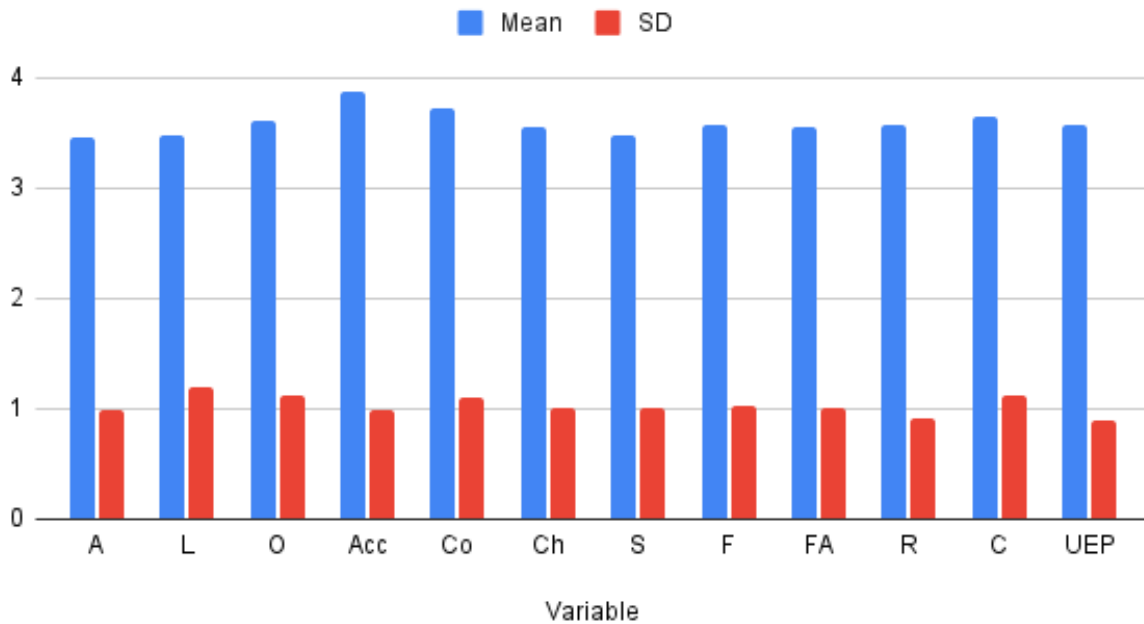
0-1	18
1-2	34
>2	18
How often do you play games?	
Very Often	8
Often	19
Neutral	15
Sometimes	15
Never	13
Mode of Interacting with G4D++	
Played in a group	27
Played individually on desktop	20
Played individually on laptop	18
Watched the game being played	5

Variables used to evaluate G4D++ and respective Mean and Standard Deviation:

		Mean	SD
A	Aesthetics	3.45	0.98
L	Learnability	3.48	1.2
O	Operability	3.605	1.115
Acc	Accessibility	3.87	0.985
Co	Confidence	3.73	1.11
Ch	Challenge	3.554	1.012
S	Satisfaction	3.482	1.002
F	Fun	3.58	1.03
FA	Focused Attention	3.55	1
R	Relevance	3.58	0.92
C	Correctness	3.65	1.13
UEP	User Error Protection	3.58	0.9

Distribution of Mean and Standard Deviation across the MEEGA+ variables:

Mean and SD



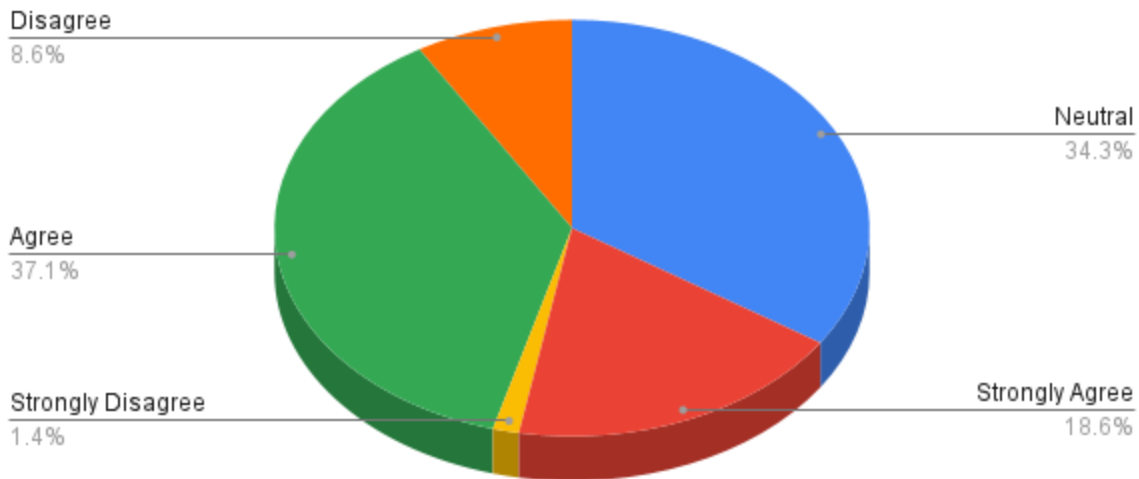
Detailed Questionnaire to evaluate G4D++ and the results of evaluation:

Variable	Questions	Mean	SD
A	The game design is attractive (interface, graphics, cards, boards, etc.).	3.45	0.98
L	I needed to learn a few things before I could play the game.	3.5	1.23
L	Learning to play this game was easy for me.	3.43	1.22
L	I think that most people would learn to play this game very quickly.	3.52	1.17
O	I think that the game is easy to play.	3.48	1.06
O	The game rules are clear and easy to understand.	3.73	1.17
Acc	The fonts (size and style) used in the game for code snippets are easy to read.	4.18	1.04
Acc	The game provides enough flexibility to play the game as per my choices (multiple avatars and difficulty level choices)	3.56	0.93
Co	When I first looked at the game, I had the impression that it would be easy for me.	3.73	1.11

Ch	This game is appropriately challenging for me.	3.69	1.09
Ch	The game provides new challenges (offers new obstacles, situations or variations) at an appropriate pace.	3.59	1.11
Ch	The game does not become monotonous as it progresses (repetitive or boring tasks).	3.38	0.96
Ch	The game promotes competition amongst the players	3.48	0.96
Ch	The game motivated me to perform better in the tasks and complete the game in the best possible time.	3.63	0.94
S	It is due to my personal effort that I managed to advance in the game.	3.4	0.99
S	The game contributed to my learning	3.63	0.94
S	I feel satisfied with the things that I learned from the game.	3.42	1
S	I would recommend this game to my colleagues.	3.43	0.98
S	Completing the game tasks gave me a satisfying feeling of accomplishment.	3.53	1.1
F	I had fun with the game.	3.58	1.03
F	Something happened during the game (game elements, competition, etc.) which made me smile.	3.58	1.03
FA	There was something interesting at the beginning of the game that captured my attention.	3.7	0.93
FA	I was so involved in my gaming task that I lost track of time.	3.58	0.99
FA	I forgot about my immediate surroundings while playing this game.	3.38	1.1
R	The game contents are relevant to my interests.	3.58	0.92
C	The clues given in the game are correct with respect to the code snippet provided	3.65	1.13
UEP	Each of the levels has a different and well-structured gameplay	3.58	0.9

According to MEEGA+, values of 3.5+ usually indicate positive response from the participants. Also, the quality score calculated based on the mean values of the variables and the cronbach alpha values defined by MEEGA+ result in the quality score of 64%. According to MEEGA+, games with quality score value less than 42.5 are considered to be of low quality, between 42.5 to 65 are considered to be of good quality and those with value greater than 65 are considered to be of excellent quality. Thus, we observe that, based on the survey results, G4D++ has a good quality level.

The game contributed to my learning



A sample question and distribution of the participant response

Suggestions & Feedback:

<i>Good game to play</i>
<i>Fell to learn new thing in a creative way</i>
<i>The game made me happy and it is fun to play.</i>
<i>The full map could not appear on some screens...</i>
<i>It is some what confusing</i>
<i>Improve the graphics and user interface</i>
<i>Please remove Null boxes at initial levels. So everyone can manage to get to next levels easily and it will be more interesting when Null boxes come in higher levels</i>
<i>Snippets are not found for long time</i>

Conclusion and Future Directions

In summary, as part of this project, we have designed and developed the G4D++ game as a multi-level treasure hunt game to teach debugging skills, which are fundamental and critical for industry jobs today. Through deployment of the game in IIT Tirupati and RGUKT, we have demonstrated that games are a powerful mechanism for teaching to the current generation of students in higher and open education. The results from the deployment demonstrate that there is immense scope to leverage games to engage students from rural, low-income and diverse backgrounds in learning important skills. As part of future work, we plan to make the game light-weight and deploy the game at scale in RGUKT and other institutions.

Acknowledgements

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