Mystery of the Pixel: Educational Game on Basic of Computer Vision

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***Abstract*—This paper presents the development and evaluation of an educational application designed to teach fundamental concepts of computer and machine vision. The game-based application, built using the Unity engine, was tested on 68 high school and university students to assess its effectiveness. Through interactive levels covering topics such as image processing, filters, and thresholding, students demonstrated a significant improvement in their understanding of the subject. The study revealed an increase in correct answers from a median of 6 to 10, indicating the potential of gamified learning in technical education. Additionally, students reported higher engagement and faster learning, suggesting that educational games can complement traditional teaching methods and boost motivation in STEM fields.**

Keywords—gamification, education, STEM, Unity, computer vision

I. Introduction

To engage today's digital-native students, it's important to explore new learning methods that connect with their comfort with technology. These students have grown up in a world surrounded by technology and the internet, creating new opportunities for learning through digital socialization. This shift allows education to move beyond traditional, purely cognitive approaches and include more social and emotional aspects [1].

Games are a great way to meet these changing needs. A well-designed game offers motivating challenges that keep players engaged by combining game mechanics with interesting stories and feedback. This creates an immersive experience where players progress smoothly. Game communities also provide a space for players to share ideas and build knowledge together. Author [2] has found that video games create environments where problem-solving and learning happen naturally. In these spaces, challenges and learning drive motivation, making games both fun and effective for education.

By using the engaging nature of games with the needs of digital-native students, educators can create more interactive and effective learning experiences that address both how students think and how they feel [3].

Traditional teaching methods and learning approaches are becoming less effective for many students. Research shows that these methods often reduce students' motivation and interest in learning programming. To tackle this challenge, several educational games, also known as serious games, have been developed to make learning programming more engaging and enjoyable [4].

II. Gamification

Gamification is a technique whose main goal is to apply game elements and mechanisms to everyday situations such as education, work or personal development. Gamification makes people more motivated to achieve specific personal milestones. The ultimate goal of gamification is to gain experience. The transfer of knowledge and information takes place through gamification. It is necessary to set up a motivating system based on reward, achievement and interaction [5].

The purpose of gamification techniques is to exploit people's natural desires for socialization, learning, self-improvement, competition, achievement, status, self-expression, altruism or closure, or simply their reaction to a situation appearing as a game. Basic gamification strategies use rewards for completing desired tasks or competitions to engage players. Types of rewards include points, badges for achievements or levels, fulfilling a progress bar, or providing virtual currency to the user. Making rewards for completing tasks visible to other players or providing leaderboards are ways to encourage players to be more competitive [6].

Another approach to gamification is to make existing tasks feel more like games. Techniques used in this approach include adding meaningful choices, introducing a tutorial, increasing the difficulty, and adding a story. The term gamification was coined in the 21st century and is derived from the word "game" [5].

However, the concept of gamification is rooted in history and has been used in the past in various domains such as military exercises or sports competitions. Gamification has flourished with the advent of modern technology but especially social networking. This development brought the concept of gameplay through apps. In 2002, Nick Pelling

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became a leading exponent of the concept of gamification, defining it as a process that breaks down the boundaries between games and real life situations [6].

A. Gamification in education

Gamification in education has sparked controversy, with some labeling it as "exploitationware," but a meta-analysis shows a significant positive effect on student academic performance [7]. The concept of gamification is being integrated into service marketing theory, emphasizing its experiential nature and highlighting important aspects such as affordances and psychological mediators [8]. There is a lack of shared understanding of gamification elements, hindering effective design, but a taxonomy has been developed to guide the gamification of information systems [9]. Gamification science aims to develop theories for designing effective gamification interventions, drawing on insights from both gamification science and games research 4. The literature on gamification's effects on motivation and engagement in education is still limited, with gaps between theory and practice and a lack of implementation guidelines [10]. Non-digital gamification methods have been explored as effective alternatives in education, showing similar improvements in learning achievement compared to digital methods [11].

There are some great examples of gamification in education that can help to create one's own gamification teaching strategy. Some of the most commonly used elements of gamification in teaching include the following [12], [13], [14] :

- Awarding points for meeting academic goals.
- Rewarding non-academic goals such as cleaning the classroom.
- Reflecting on personal performance through charts and visual indicators.
- Using levels and checkpoints as an indicator of progress through the game. In this way, students want to know what happens next, which keeps their attention focused on learning.
- Badges are an effective alternative to checkpoints. These implement an element of competition into the classroom, which can create a sense of community and increase the level of engagement in the classroom.
- Using different platforms or apps. Teachers can achieve student engagement by using tablets, smartphones, and other options that allow students to access their learning resources anytime, anywhere.

III. EDUCATIONAL GAME - COMPUTER VISION: THE MYSTERY OF THE PIXEL

The goal of our work was to create an educational application that will be used to teach the basics for further studies in the field of computer and machine vision. The expectations and benefits of our educational application:

- The player will gain a basic understanding of computer and machine vision.
- Increased interest among high school students in studying engineering.
- Increase the interest among high school students to study computer and machine vision issues.
- Increased interest in game design among gamers.

Functional requirements that define the direct functionality of our application:

- Player movement - The player can move in four directions: right, left, up, and down using the keys (w, s, a, d) (see Fig. 1 - 1).
- NPC Dr. Pixel panel - When near Dr. Pixel, a panel with text, images, and a "Next" button appears (Fig. 1 - 2). Pressing it shows the next panel or hides it, revealing Dr. Pixel or the tutor NPC.
- Lecturer NPC panel - Similar to Dr. Pixel, but only text and possibly images are shown (Fig. 1 - 3). Clicking the panel reveals a new one with a question and hint (see Figure 43). Answers are entered or selected, then confirmed by a left-click.
- Portal Guardian NPC panel - The panel with questions is displayed (Fig. 1 - 4). The player answers sequentially, but results are revealed only after all questions are answered.
- Answer checking - Correct answers increase the score, and either Dr. Pixel or the tutor NPC appears. After answering all Portal Guardian questions, the player can move to the next level or retry. Incorrect answers show a panel with the error (Fig. 1 - 5). The player can retry the question or the entire set.
- Level transitions - Levels one to three end with Portal Guardian NPC questions, and the final level ends with Capt. Segmet. After answering all questions, a statistics panel appears.
- Final stats - After completing Capt. Segmet's questions, a final statistics panel displays correct and incorrect answers (Fig. 1 - 6).
- Music for each level - Background music plays during levels and stops when the player advances or when final stats are displayed. Final music plays at game completion.
- Exiting the app - The player can exit the game by pressing the "Exit Game" button. After the final question, the player is informed if all answers were correct.

The application include an introduction screen, an information screen, three levels and a final screen. The introduction screen displays the name of the educational app and a "Start Game" button. The introduction screen will be displayed immediately after the app is turned on. Pressing the button is followed by the information screen, which provides a brief introduction to the subject matter. It then goes to the first level where the player will learn what an image is , its color distribution what the color depth of each image is, how an image is sensed and what an image histogram is. The second level explains the Gaussian filter, Laplace filter and edge detection in an image. In the last level, the player will learn what segmentation, thresholding and what are the disturbing phenomena in an image. In each level there are:

- The NPC of the main teacher, next to which the tutorial text is displayed. The teacher NPC will be the same in all levels.
- NPCs of assistant tutors, at which the tutorial text and question bar will appear.
- NPC of the guardian, at which four questions will be displayed.
- An NPC captain who will verify the player's acquired knowledge. It will be at the end of the last level.

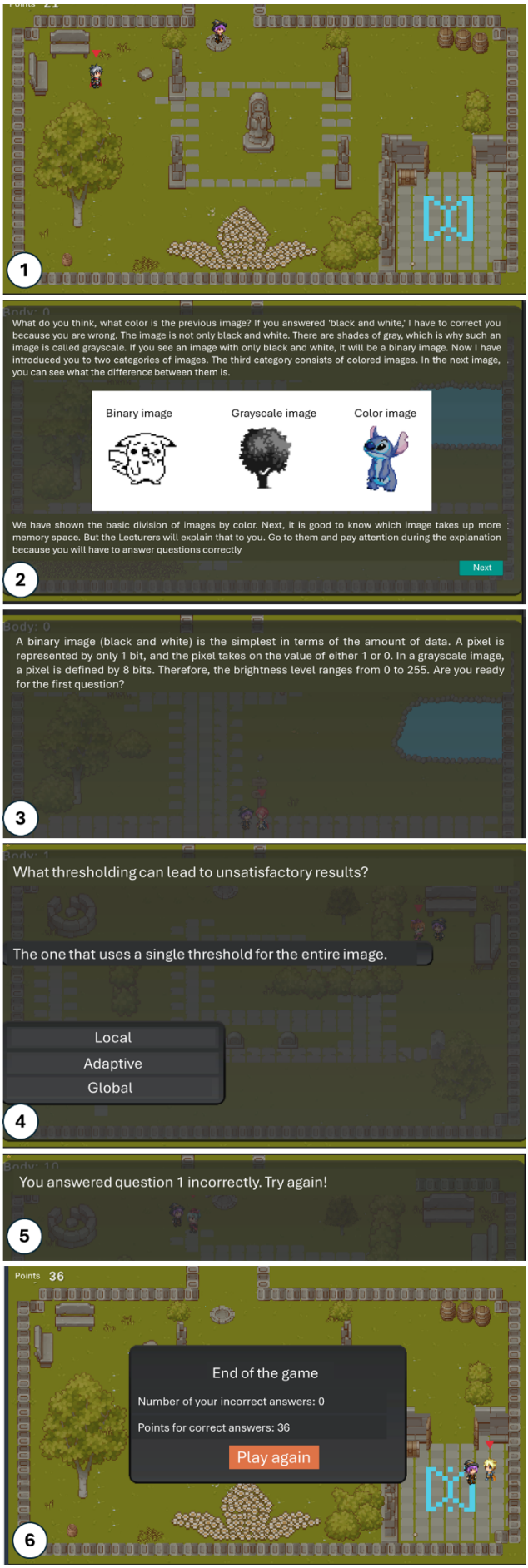

Fig. 1. Functionalities of the game.

At the beginning of each level there will be only the main teacher who will explain to the player the given part of the problem, which will be divided in several panels. The panel with the text will only appear when the player gets close to the teacher. Between the panels the player will scroll by clicking the left mouse button. If the last panel is displayed and the player left clicks anywhere, the 3 lecturers will appear and the main teacher will be hidden.

The player will be able to choose which tutor to go to first. When the player stands in front of the tutor, a question will be displayed for the player to answer. If he answers correctly, that tutor hides and can go to another tutor. If the answer is incorrect, a panel will appear to alert the player that he has answered incorrectly. The panel with the question will then reappear.

If the player answers all the questions from the tutors correctly, a guard appears in the level behind and asks the player four questions related to the part of the problem explained. If he answers one of them incorrectly, he must answer all the questions again. If the answer is correct, he will be shown the path to the next level.

A. Implementation of the game

We developed the educational application in the Unity game engine, which we chose based on a detailed analysis and previous experience. Unity's simple architecture, wide range of asset packages and strong community of programmers who share their knowledge and experience on various forums make Unity a suitable tool for creating games and various applications, which is why we chose it to implement our educational game.

Two assets from the Asset store were used to design the levels. First, we chose the asset Pixel Art Top Down - Basic [15], from which we used tiles to create the tile map, see Fig. 2 - 1. Prefabs of grass, trees, bushes, stones, barrels, crates and various stone formations to complete the level design, see Fig. 2 - 2. Prefab stands for prefabricated object and is created as an entity that contains visual and functional components. From the second asset, Fantasy dot Character Pack 2 [16], we used the characters for the player character, the NPC Dr. Pixel, the lecturers, the Portal Guardian, and Capt. Segment, see Fig. 2 - 3.

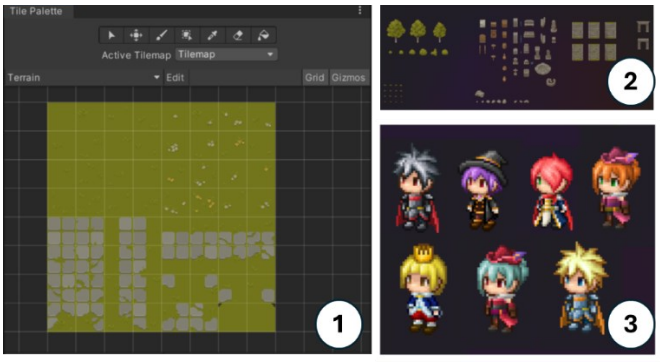

Fig. 2 Used Palette Tiles (1), Prefabs (2) and Characters (3).

IV. TESTING OF THE GAME

We tested the effectiveness and functionality of our educational application using a study involving 68 respondents from high schools and colleges, 55 of whom were male and 7 were female. While only 62 of them completed all the steps of the testing which consisted of three items:

1. Completion of an initial questionnaire - In this questionnaire, we collected basic information about the respondent and his/her knowledge of computer and machine vision topic before running our educational application.
2. Playing the game - While going through each level, the respondent was familiarized with the topic.
3. Completing the output questionnaire - In this questionnaire, we surveyed the knowledge of the respondent after running our learning application.

The input questionnaire consisted of two parts : basic information about the respondent and questions that tested the knowledge of the respondent regarding computer and machine vision problems.

The output questionnaire consisted of three parts, the first two were the same as in the input questionnaire and the third one was about the personal opinion about our educational application.

The aim of the evaluation of the input and output questionnaire was whether the students improved their knowledge of the topic after playing the educational game.

The knowledge multiple choice test questions were as follows:

- How many values does a binary image have?
- What color is this image?
- What colors does the RGB color model contain? (There are 3 correct options)
- What is the name of the graph in this image?
- Which filter is used for edge detection?
- When does the brightness change in image? (There are 3 correct options)
- What is the following image a result of?
- Based on which properties is the image divided during thresholding?
- What is the Otsu method used for?
- Which of the disruptive phenomena is present in the image?
- How does vignetting appear in an image?

A. Results of Testing

During the functionality testing we found several bugs, which we subsequently removed and corrected, or added the required functionality.

We have modified the player movement. If a text or question bar is displayed, the player is unable to move. We have secured all sides of the board so that the player cannot exit the board. Lastly, we've fixed the errors that were present in the text.

Respondents stated in their answers that they missed a button to turn off the app from each location in the game. Based on these responses, we modified the button so that the player is able to close the app even when the text or question bar is currently displayed.

The question "How old are you?" was in the "Personal details" section, the age of the respondents is shown in Fig. 3.

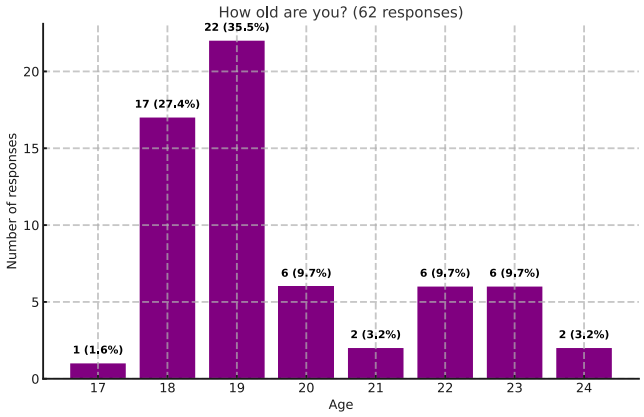

Fig. 3 Graph from the exit questionnaire showing the age of the respondents

Most of the respondents were from secondary schools (Bratislava and Nitra region, Slovakia), more than 60%, see Fig. 4.

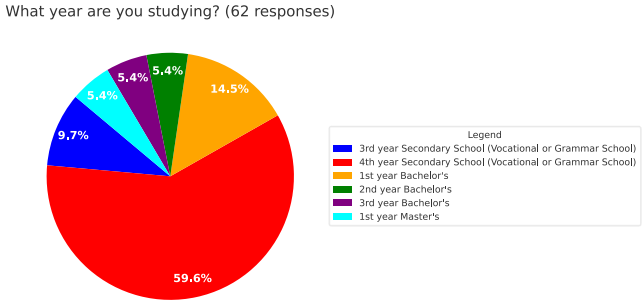

Fig. 4 Chart from the exit questionnaire showing what schools and grades respondents are studying at

To the question "Are you familiar with the concept of Computer and Machine Vision?" respondents answered as follows, see. Fig. 5.

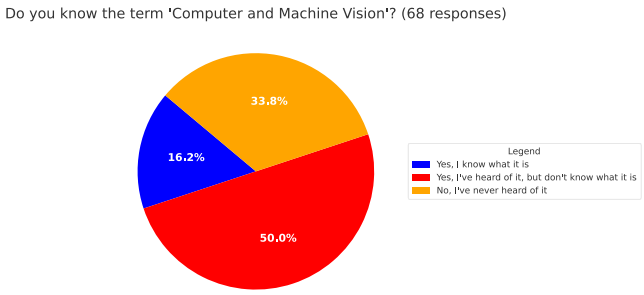

Fig. 5 Graph from the entry questionnaire, showing respondents' answers

Fig. 6 and Fig. 7 show the distribution of correct responses to the input and output questionnaires. It should be noted that 68 respondents completed the input questionnaire and only 62 respondents completed the output questionnaire.

In the output questionnaire, in the "Questions about the Game" section, we collected, how many questions the respondent answered incorrectly and the number of points scored for correct answers learned in the statistics.

Fig. 8 shows the distribution of points obtained and Fig. 9 shows the distribution of incorrect answers.

In the questionnaire, we also investigated whether the respondents would learn the selected topic faster and more efficiently with the help of educational applications and what our educational application motivated them to do. These results from the questionnaire is shown in Table 2.

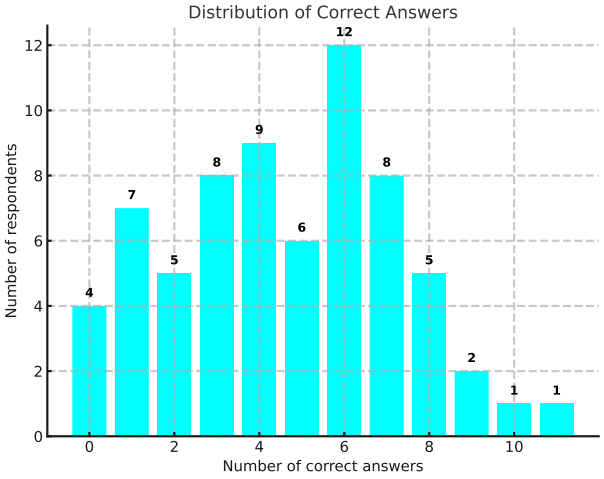

Fig. 6 Graph from the input questionnaire showing the frequency of correct answers for 68 respondents

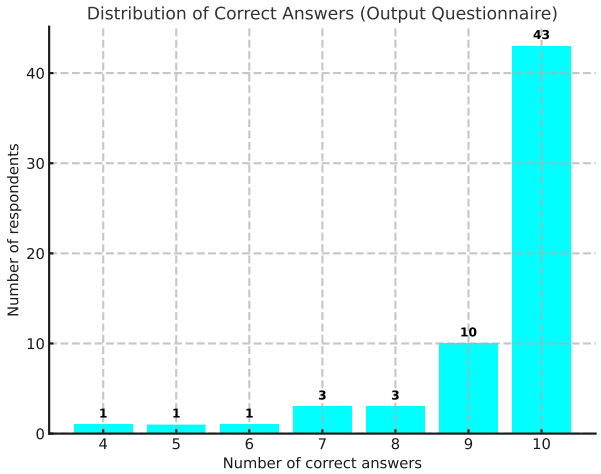

Fig. 7 Graph from the input questionnaire showing the frequency of correct answers for 62 respondents

Table 2 shows the median and mean number of correct responses from both questionnaires.

TABLE I. MEDIAN AND AVERAGE NUMBER OF CORRECT ANSWERS IN THE QUESTIONNAIRES

	Input Questionnaire	Output Questionnaire
Median number of correct answers	6	10
Average number of correct answers	4.61	8.4

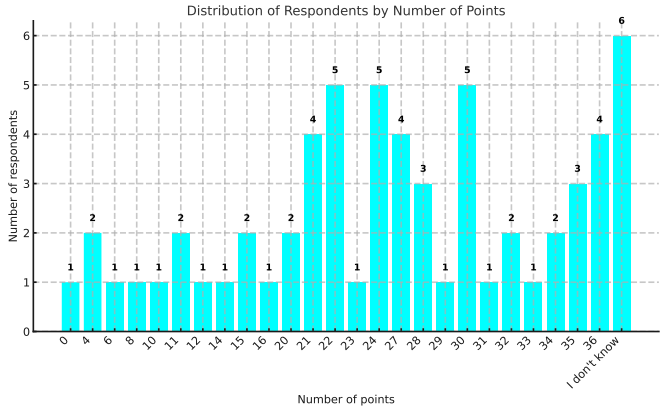

Fig. 8 Graph from the output questionnaire showing the distribution of points scored in the game

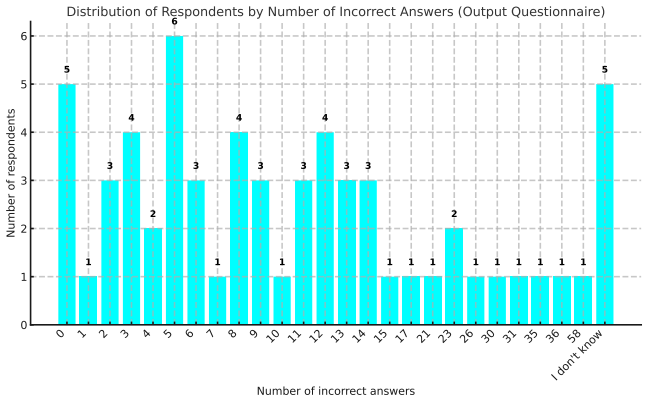

Fig. 9 Graph from the output questionnaire showing the distribution of incorrect answers in the game

TABLE II. RESULTS FROM THE OUTPUT QUESTIONNAIRE (OPINIONS)

	Strongly agree [%]	Partially agree [%]	Slightly agree [%]	Cannot assess [%]	Slightly disagree [%]	Partially disagree [%]	Strongly disagree [%]
The respondent understood the explained topic	51.6	36.7	8.1	0	0	0	1.6
The topic was too complex for the respondent	16.1	17.7	33.9	11.3	3.2	9.7	8.1
The respondent learned faster and more effectively using educational applications	41.9	48.4	4.8	3.2	1.6	0	0
Motivation to study in a technical field	14.5	35.5	29	9.7	0	4.8	6.5
Motivation to study computer vision and machine learning	12.9	21	35.5	17.7	1.6	3.2	8.1
Motivation to develop games	14.5	21	25.8	24.2	1.6	4.8	8.1

B. Summary of the Testing Results

Based on the graphs and data from the educational game testing, several conclusions can be drawn:

1. **Increased Knowledge after Gameplay:** The comparison between the input and output questionnaires shows a clear improvement in knowledge after engaging with the educational game. The median number of correct answers increased from 6 to 10, and the average number of correct answers increased from 4.61 to 8.4. This demonstrates that the game had a positive impact on the respondents' understanding of computer and machine vision concepts.
2. **High Engagement with Educational Game:** The distribution of correct answers and the respondents' opinions indicate that the game was engaging and effective in conveying the intended educational content. Many respondents indicated that they understood the explained topics well, with 51.6% strongly agreeing and 36.7% partially agreeing.
3. **Challenges in Complexity:** Although the majority found the game helpful, 33.9% of respondents slightly agreed that the topic was too complex, with 17.7% partially agreeing and 16.1% strongly agreeing. This shows that while the

game was effective, some users may have found certain topics challenging.

4. **Learning Efficiency:** Respondents reported that the educational game helped them learn faster and more effectively, with 41.9% strongly agreeing and 48.4% partially agreeing. This suggests that the interactive and gamified nature of the application helped improve learning efficiency.
5. **Motivation to Study and Learn:** The game appears to have motivated students to engage more with technical fields, including computer and machine vision. 35.5% of respondents were motivated to study technical topics, while 35.5% were also encouraged to learn more about computer vision and machine learning. Additionally, 14.5% strongly agreed that the game increased their motivation to pursue game development.
6. **Room for Improvement:** While the game was successful overall, there were areas of feedback, including some respondents feeling that a small percentage of questions were too complex. Moreover, some respondents suggested that the game could benefit from added functionality such as the ability to close the game from any location.

V. Conclusion

The goal of this study was to spark interest in game creation and technical studies for high school and university students, while providing knowledge in computer and machine vision. The educational application, built using Unity, featured four levels covering image processing concepts like image models, filters, noise, segmentation, and thresholding. Students tested their knowledge with theoretical questions after each level.

In a study with 62 participants, results showed that students acquired basic computer and machine vision knowledge through educational application, highlighting its potential as an innovative learning tool. The game-based approach proved effective for student learning and understanding, complementing traditional teaching methods.

Our testing assumption was confirmed by the significant increase in correct answers between the input and output tests. We hypothesized that the educational application would spark interest in studying engineering, gaining computer and machine vision knowledge, and game creation. Respondents rated the game positively, reflected in the exit questionnaire results.

Future improvements could include adding advanced levels, introducing difficulty settings tailored to different user skill levels, gathering more feedback from a geographically and academically diverse group of participants, and conducting comparative studies with traditional teaching methods to refine and validate the educational application.

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