EpicGlote: An Educational Minigame for Teaching Epiglottis Function

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Abstract. Introduction*: Teaching dynamic physiological processes such as the swallowing mechanism and the protective function of the epiglottis can be challenging when using only static anatomical representations.* ***Objective:*** *This work presents the design and development of an educational game focused on teaching the anatomy and function of the epiglottis during swallowing.* ***Methodology****: The game combines narrative contextualization with interactive mechanics in which players control a simplified simulation of epiglottic movement to prevent food from entering the airway while managing airflow, supported by a real-time 3D anatomical model. The MEEGA+ instrument was used to evaluate usability and player experience with 37 participants.* ***Results:*** *MEEGA+ results indicated positive acceptance of the game across multiple dimensions (overall mean 3.72/5), with the highest scores observed in Operability (4.32), Perceived Learning (4.28), Learnability (4.27), and Relevance (4.19). The game achieved a good IRT quality score (47.90), suggesting positive educational potential as a complementary tool for anatomy learning.*

Keywords *Serious Games, Anatomy Education, Epiglottis, Game-Based Learning, Educational Technology.*

1. Introduction

Human anatomy is one of the fundamental disciplines in the health and biomedical fields. Like other disciplines, it has undergone significant transformations resulting from the incorporation of digital technologies into education and from changes in the student profile, which is increasingly aligned with the concept of digital natives [Henssen et al. 2020, Stiver et al. 2025]. In this context, educators have adapted their pedagogical strategies by incorporating digital tools, such as interactive simulations

of the human body, into anatomy teaching [Cullinane et al. 2023], which can act as a complement to both lectures and laboratory-based practical classes [Adnan et al. 2024].

Another relevant factor concerns the limitations associated with traditional anatomy teaching, historically based on the use of cadavers. Difficulties related to access, costs, and availability of these resources, as well as challenges in the three-dimensional visualization of anatomical structures, have been reported in the literature [Kurul et al. 2020, Ma et al. 2016]. In this context, the need for more flexible and interactive alternative methods has driven educational institutions to seek new approaches. Thus, technologies such as virtual reality, augmented reality, and educational games have been progressively incorporated into different health-related courses [Bork et al. 2021, Du et al. 2020, Yow 2022].

Among these approaches, digital games have stood out as promising tools, as they promote engagement, motivation, interactivity, and content retention [Ricciardi e de Paolis 2014, Zhonggen 2019]. However, there are still gaps regarding how these games integrate complex anatomical content with learning assessment and functional contextualization of structures. In particular, regions such as the head and neck present high levels of complexity, requiring students not only to memorize structures but also to understand their interactions during vital functions.

In this sense, this study proposes the development of an educational game aimed at understanding the epiglottis and its contribution to airway protection during swallowing. The game places the player in an interactive environment in which they control a fictional defense-cell character representing the protective mechanisms involved in the passage of air and food through the laryngopharyngeal region. Through contextualized dialogues, the player receives information about the function of the epiglottis and must act to prevent food from entering the laryngeal airway during swallowing.

To evaluate the proposal, a pilot study was conducted with lay participants, using an approach based on interaction with the game followed by assessment through interpretative questions[1]. This work focuses on evaluating user reception and user experience regarding the developed game rather than measuring learning outcomes. The assessment of learning outcomes is beyond the scope of this paper and is the subject of ongoing work.

As a contribution, this work presents an accessible and low-cost approach to teaching functional anatomy, using digital games as a means to promote the understanding of complex physiological processes. In addition, it seeks to answer the following research question: (RQ) How is the educational game received by lay users?

2. Related Works

Recent studies have investigated the use of digital games as educational tools in health education, focusing on increasing engagement and improving learning. [Buajeeb et al. 2024] developed a simulation-based serious game for teaching diagnosis and treatment planning of oral lesions to dentistry students. The study, conducted with 75

[1]In accordance with Article 1 of CNS Resolution No. 510 of 2016 and Article 26 of CNS Resolution No. 674 of 2022, this research does not require approval from the Ethics Committee, particularly because it involves the collection of anonymized opinions.

participants, demonstrated a significant improvement in student performance after using the game, showing results equivalent to traditional lecture-based methods. However, the proposal is directed toward clinical contexts and students with prior background in the field, which limits its application to lay audiences or early stages of learning.

Similarly, [Castellano et al. 2024] proposed an interactive digital tool for teaching human anatomy, incorporating features such as challenges, recommendation systems, and virtual assistants. The application was evaluated with 131 students, showing improvements in academic performance and content retention. Despite the positive results, the approach focuses mainly on interaction with questions and automated feedback, with less exploration of immersive elements related to the physiological functioning of the studied structures.

Unlike the aforementioned works, the present study proposes a digital game aimed at the functional understanding of the epiglottis within the context of the upper airways. The proposal places the player in a narrative-driven environment in which they interact with a simplified representation of swallowing, supporting the understanding of how epiglottic movement contributes to airway protection. In this way, the game seeks not only to reinforce the recognition of anatomical structures but also to promote the understanding of their function in everyday situations, making the content accessible to lay audiences as well.

3. Game Design

3.1. Game Structure and Flow

Each aspect of the game was developed with the support and feedback of anatomy education specialists. Their contributions guided the definition of learning objectives, dialogues and gameplay mechanics, ensuring an anatomically accurate representation. The overall development sequence is illustrated in Figure 1.

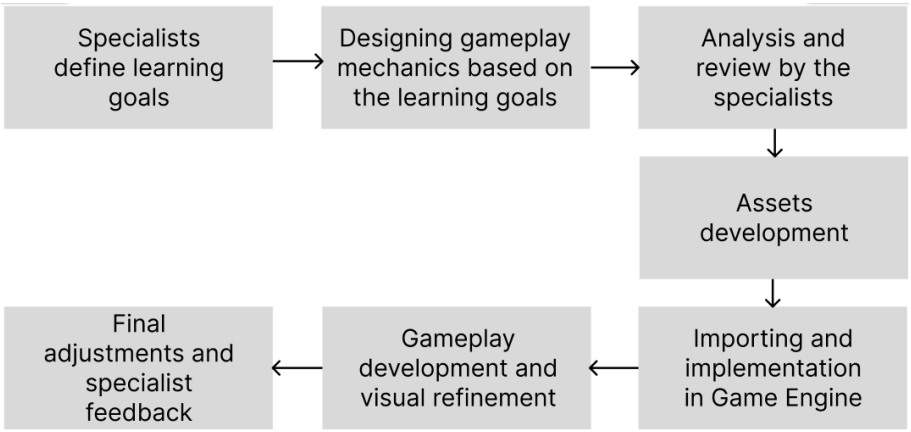

Figure 1. Development Sequence Diagram.

The game starts in the main menu, presenting the options to play, see the credits, and exit the game if the player intends to. Once the player selects to play, they will see the main part of the game, where the main gameplay takes place. The game is structured in three parts: theoretical contextualization, practical interaction, and final feedback. The

player is directed to a dialogue sequence, that introduces the anatomical location of the epiglottis and its contribution to airway protection during swallowing (Figure 2).

At this stage, the dialogue presents an everyday situation in which epiglottic movement contributes to airway protection, specifically during swallowing in the context of a meal. This presents a challenge to the player while simultaneously teaching them in what situations the epiglottis is used. After the dialog, the gameplay starts.

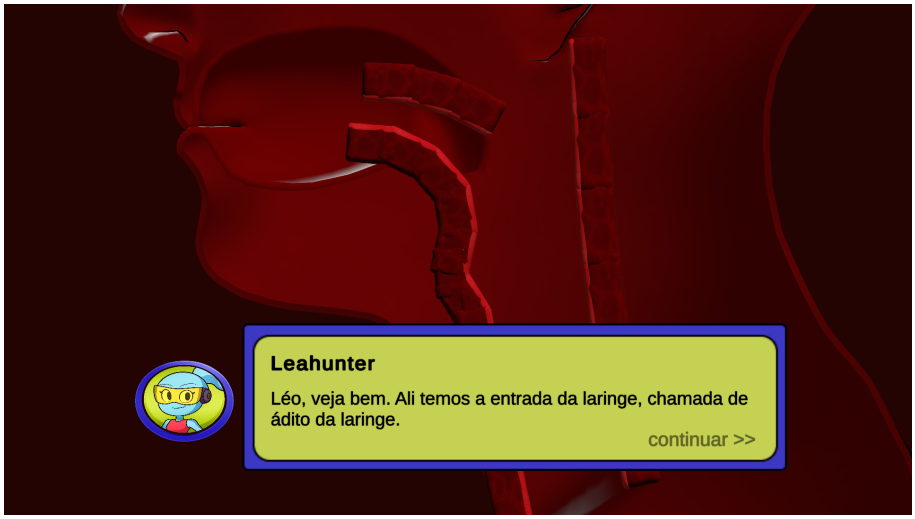

Figure 2. Dialogue interface presenting educational content about epiglottis prior to the gameplay.

3.2. Game Mechanics

The player must trigger epiglottic inversion to control the passage of food and air, via keyboard input (spacebar) on PCs, or touch input (UI button) on mobile. For every piece of food or air that goes to the correct location, the player receives 1 point. The player must manage the use of the epiglottis according to the amount of oxygen available, as the simulated movement of the epiglottis temporarily blocks airflow. Furthermore, the player must also be careful not to let food enter the trachea. If this happens, the food causes choking and abruptly reduces the player's oxygen level. Once the player reaches 100 points or runs out of oxygen, the game ends.

3.3. Anatomical Representation and Feedback

During swallowing, the epiglottis plays an essential role as a protective mechanism of the airways, temporarily tilting to prevent the entry of food or liquids into the larynx, directing them toward the esophagus. After the passage of the food bolus, this structure returns to its initial position, allowing breathing to resume. Thus, the proper functioning of the epiglottis is fundamental to prevent events such as choking and aspiration of content into the respiratory tract.

In order to represent the location and function of the epiglottis, we used a 3D background model so that the player can have a broad view of the described scenario, where food goes down the throat and the inspiration and expiration processes. The internal cavity and epiglottis are presented in a 3D representation from a lateral perspective, in

order to illustrate the pathways of food and air, as well as the movement of the epiglottis (Figure 3).

The game was designed as a complementary tool for learning the anatomy of the epiglottis, in a way that could be applied in the classroom by instructors. The game reinforces knowledge learned in traditional classes through an interactive and entertaining approach. This strategy is based on constructivist principles, which state that learning occurs through practical experiences, experimentation and in an active manner.

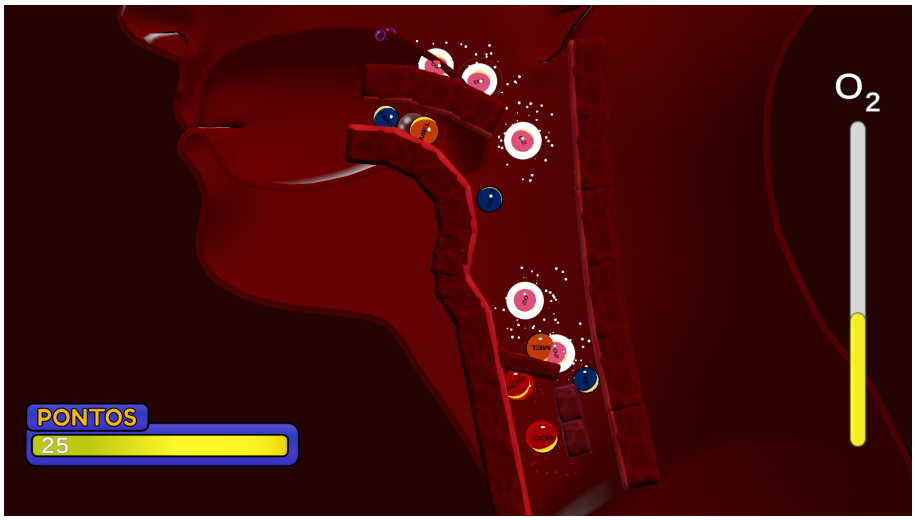

Figure 3. Gameplay simulating epiglottic movement during swallowing.

4. Methods

4.1. Study Design

This study follows a quantitative methodology to assess the educational effectiveness and user experience of the proposed game. Data collection was carried out using the MEEGA+ questionnaire, structured in two stages: an initial survey to gather demographic information, followed by the MEEGA+ instrument to capture participants' perceptions of usability and player experience through Likert-scale items.

The materials used included the educational game "EpicGlote" developed with Unity and an online survey administered via Google Forms. The survey instrument corresponded to the MEEGA+ model for evaluating user experience.

All procedures were conducted remotely. The questionnaire was distributed through researchers' social media profiles, mailing lists, and messaging application groups. Participants accessed the survey online and were required to provide informed consent before proceeding. After completing the demographic section, they were instructed to download and interact with the game, with access and execution guidelines provided through a link embedded in the form. Upon completing the gameplay session, participants responded to the MEEGA+ questionnaire.

The evaluation framework comprised two components: demographic profiling and user experience assessment. The demographic section included variables such as

age, gender, educational level, state of residence, income bracket, and frequency of engagement with digital and non-digital games, enabling characterization of the sample.

User experience and usability were assessed based on the MEEGA+ model [Petri e von Wangenheim 2018], which examines dimensions including focused attention, challenge, satisfaction, confidence, relevance, perceived learning, and enjoyment, using a five-point Likert scale. The model consists of 29 standardized items and recommends additional items related to perceived learning; in this study, three such items were developed.

Therefore, the dimensions corresponding to each question number are: Aesthetics (Q1-Q2), Learnability (Q3-Q5), Operability (Q6-Q7), Accessibility (Q8-Q9), all related to the usability factor; and Confidence (Q10), Challenge (Q11-Q13), Satisfaction (Q14-Q17), Social Interaction (Q18-Q20), Fun (Q21-Q22), Focused Attention (Q23-Q25), Relevance (Q26-Q29), and Perceived Learning (Q30-Q32), all related to the player experience factor. The full questionnaire is presented in our supplementary material in Section A.

4.2. Participants

The tests had 39 participants, however, two participants failed an attention check test, asked in pre-test and post-test sections, developed accordingly stablished recommendations [Pei et al. 2020, Kung et al. 2018, Silber et al. 2022].

Therefore, we had 37 valid participants, the majority of them identified as cisgender men (n = 30, 81.08%), followed by cisgender women (n = 6, 16.22%) and 1 participant who preferred not to identify their gender (n = 1, 2.70%). Most respondents reported incomplete higher education (n = 19, 51.35%). Complete higher education was reported by 13 participants (35.14%), while complete secondary education was reported by 5 participants (13.51%). Participant ages ranged from 19 to 60 years, with a mean of 27.7 years (SD = 11.34). The most frequent ages were 20 years (n = 6, 16.22%) and 22 years (n = 11, 29.73%), followed by 19 years (n = 4, 10.81%). All participants were from Brazil. The majority lived in São Paulo (SP) (n = 34, 91.89%). Other states included Minas Gerais (MG) (n = 2, 5.41%) and Rio de Janeiro (RJ) (n = 1, 2.70%). The most common income bracket was “5 to 10 minimum wages” (n = 11, 29.73%), followed by “1 to 3 minimum wages” (n = 10, 27.03%), “3 to 5 minimum wages” (n = 7, 18.92%) and “Prefer not to say” (n = 6, 16.22%). Two participants reported income above 10 minimum wages (5.41%) and one participant reported income up to 1 minimum wage (2.70%).

Daily digital gaming was the most frequent response (n = 13, 35.14%), followed by weekly gaming (n = 10, 27.03%) and rare gaming (n = 9, 24.32%). There were three participants reported playing digital games monthly (8.11%) and two participants who reported that never plays (5.41Playing non-digital games rarely was the predominant response (n = 21, 56.76%). Monthly playing was reported by 10 participants (27.03%), while 4 participants never plays (10.81%) and 2 played weekly (5.41%).

4.3. Data Analysis

The collected data were examined using descriptive statistical techniques, following the recommendations of the MEEGA+ authors [Petri e von Wangenheim 2018]. For the assessment of user experience, responses obtained through the MEEGA+ instrument

were analyzed descriptively across each dimension, where higher mean values reflect more favorable perceptions in terms of usability, engagement, enjoyment, and perceived learning. All statistical analyses were performed using a script implemented in the R programming language. For each item, the distribution of responses was reported, along with the corresponding median values and Item Response Theory (IRT)-based average scores, in accordance with the procedures and script provided by the MEEGA+ authors.

5. Results

The study included 37 valid participants. The analysis focused on the research question: (RQ) How is the educational game received by lay users? According to the MEEGA+ results, the game was well received by the participants. The overall average score was 0.72 on the original -2 to +2 scale, which translates to 3.72 on a 1-to-5 Likert scale. The reliability of the data was very strong, with Cronbach's Alpha reaching 0.94 and McDonald's Omega Total reaching 0.96, indicating excellent internal consistency.

Regarding the evaluated dimensions, we present the average score for each factor based on the original MEEGA+ structure [Petri e von Wangenheim 2018]. The highest ratings were observed for Operability (4.32), Perceived Learning (4.28), Learnability (4.27), Accessibility (4.20), and Relevance (4.19). These results indicate that participants found the game intuitive to use, easy to learn, accessible, relevant to their context, and visually adequate, with Aesthetics (3.99) also scoring favorably. The lowest mean was recorded for Social Interaction (2.77), which was anticipated given that the game does not emphasize multiplayer or collaborative mechanics. The full breakdown of MEEGA+ dimensions is illustrated in Figure 4.

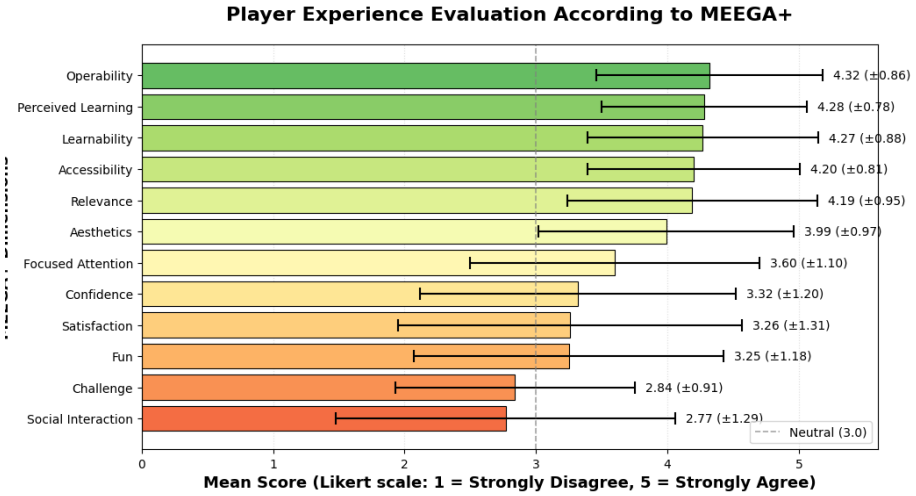

Figure 4. MEEGA+ assessment of player experience for each evaluated dimension.

Figure 5 presents the response distribution for each question of the Usability factor, using the -2 to 2 scale. Most answers were positive, with "Strongly Agree" being the most frequent, followed by "Agree". The lowest-performing questions were Q2 ("The texts, colors, and fonts are consistent and well combined") and Q5 ("I think most people would learn to play this game quickly"). Nevertheless, all items had a median of 2 ("Strongly Agree"), except for Q2, which had a median of 1 ("Agree"). Thus, the usability of the game was rated favorably.

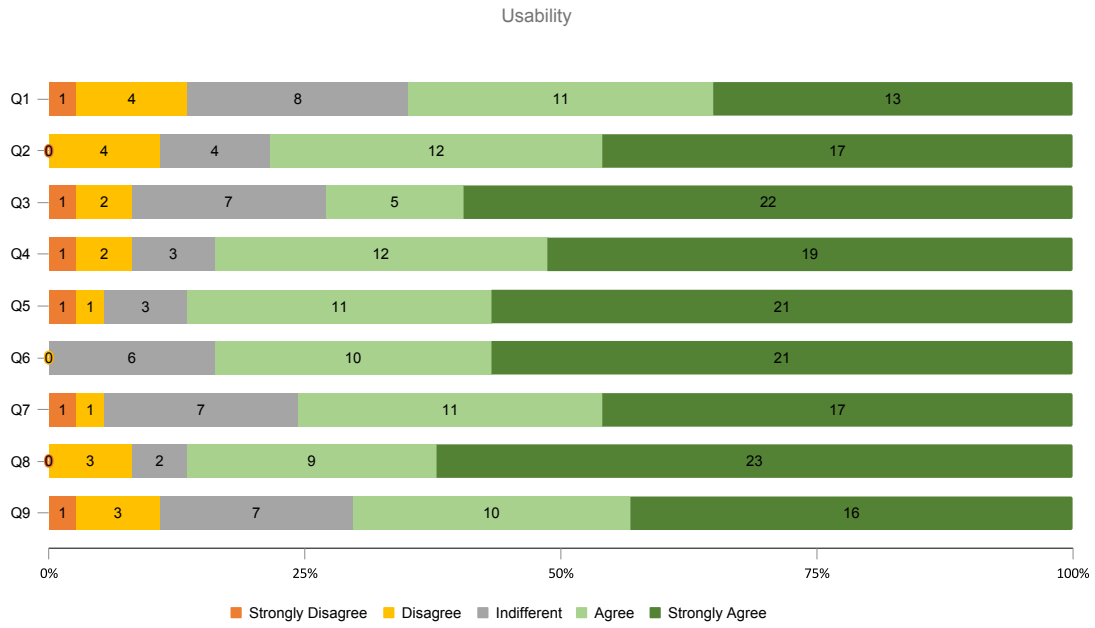

Figure 5. Frequency of answers for the Usability factor

Figure 6 displays the response frequency for each question within the Player Experience factor. While the majority of items received mostly positive answers, some items obtained a greater proportion of neutral responses, with a median of 0. These items include: Q12 – “The game provides new challenges (new obstacles, situations, or variations) at an appropriate pace.”; Q14 – “The game does not become monotonous in its tasks (repetitive or with boring tasks).”; Q15 – “Completing the game’s tasks gave me a sense of accomplishment.” and Q26 – “I forgot about my surroundings while playing this game.“ This suggests that, although the overall player experience was positive, aspects related to novelty, monotony, sense of accomplishment, and immersion were perceived more moderately by participants.

Three items had negative means. As expected, Q19 and Q20 (related to social interaction) had low scores due to the single-player nature of the game. Interestingly, Q18 ("I would recommend this game to my colleagues") also had a negative mean (-1), suggesting low recommendation intention, which may be related to the game’s repetitive mechanics and lack of challenge progression.

According to the MEEGA+ Item Response Theory analysis, the game achieved a quality score of 47.90, placing it in the "good" quality range (above 42.5 but below 65) [Petri e von Wangenheim 2018]. Written feedback, though briefly summarized here due to space limitations, was mostly positive, with participants valuing the game’s educational and playful aspects. The main suggestions for improvement included enhancing interface clarity (e.g., better color contrast, clearer anatomical structures and instructions) and introducing progressive difficulty and additional challenges to reduce repetitiveness and increase engagement.

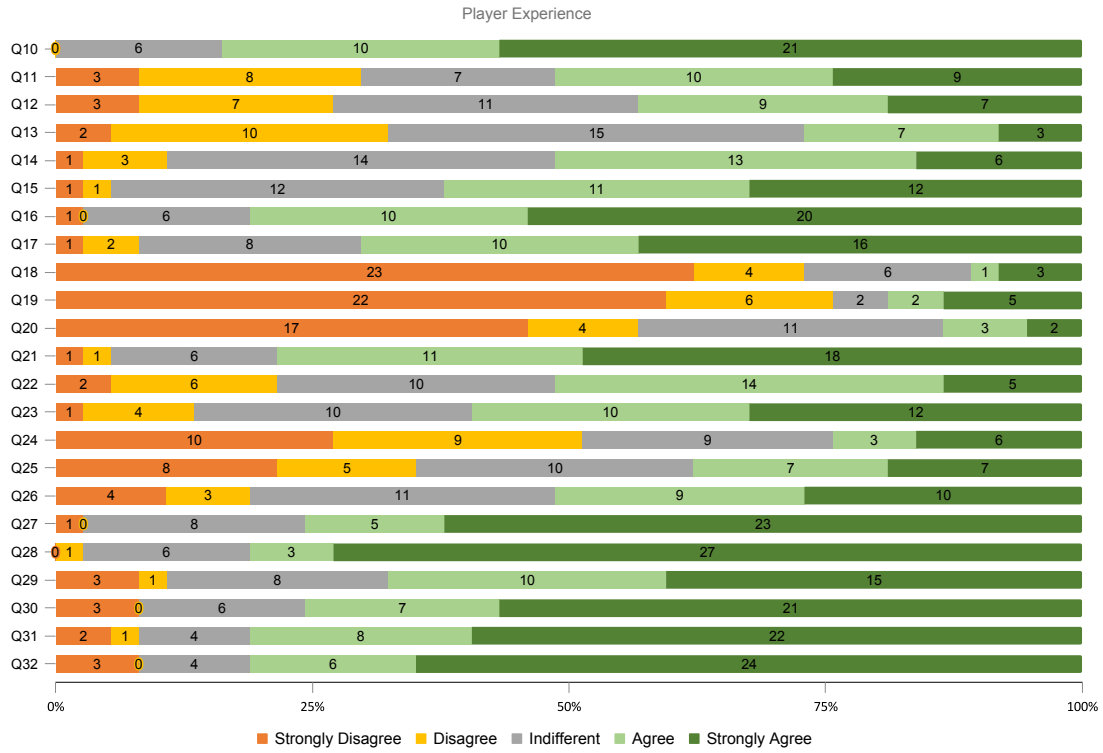

Figure 6. Frequency of answers for the Player Experience factor.

6. Discussion and Implications

According to the MEEGA+ results, the proposed educational game about the epiglottis was favorably received by the 37 participants. The overall mean score was 0.72 on the -2 to +2 scale, which converts to 3.72 on a 5-point Likert scale, indicating a positive assessment. The internal consistency was remarkably high, with Cronbach's Alpha = 0.94 and McDonald's Omega = 0.96, confirming the reliability of the responses.

The dimensions that scored highest were Operability (4.32), Perceived Learning (4.28), Learnability (4.27), Accessibility (4.20), and Relevance (4.19), suggesting that players considered the game easy to learn, intuitive, accessible, and educationally valuable. Aesthetics (3.99) also received a favorable rating, reflecting a generally positive impression of the game's visual design. At the item level, usability questions were largely positive, with most showing a median of 2 (Strongly Agree), except for Q2 (consistency of texts, colors, and fonts), which had a median of 1 (Agree). These results confirm solid overall usability.

However, a more detailed look at Player Experience items revealed some neutral medians (0), especially for Q12 (challenge pacing), Q14 (monotony), Q15 (sense of accomplishment), and Q26 (immersion, such as forgetting one's surroundings). This suggests that while the game effectively promotes learning and initial engagement, repetitive mechanics and limited progression may reduce immersion over extended play sessions. As anticipated, the lowest scores were related to social interaction (Q18–Q20), with Q18 and Q19 showing a median of -1 and Q20 a median of 0, which aligns with the single-player nature of the game.

The game obtained an IRT quality score of 47.90, surpassing the "good" threshold of 42.5 but falling short of the "excellent" benchmark of 65, thus classifying it as good quality within the MEEGA+ framework. Enhancements in challenge progression, gameplay variety, interface clarity, and sustained engagement could help the game reach an excellent level. For educators, the game provides an interactive medium to demonstrate the functional role of the epiglottis during swallowing—a physiological concept often difficult to grasp through static diagrams alone. For developers, these findings reinforce that integrating game mechanics with anatomical visualization and contextualized challenges directly supports perceived learning and educational relevance.

6.1. Threats to Validity and Limitations

The sample was predominantly composed of young, highly educated male participants from São Paulo who were already familiar with digital games, which limits generalizability. Self-report bias, the absence of objective learning measures, and the short exposure time (single session) are additional limitations. The game also presents a simplified representation of epiglottis functioning, which may limit learning depth for more advanced learners. Despite these limitations, the use of a validated instrument, attention checks, and IRT analysis provides a rigorous evaluation.

7. Conclusion

This study introduced an educational game designed to teach the anatomy and function of the epiglottis during swallowing. Players are tasked with controlling the simulated movement of the epiglottis to prevent food from entering the airway while managing oxygen flow, all supported by a real-time 3D anatomical model. An evaluation involving 37 participants, conducted with the MEEGA+ framework, revealed positive reception, with highest scores observed in Operability (4.32), Perceived Learning (4.28), Learnability (4.27), and Relevance (4.19). The game obtained a "good" quality rating according to the IRT-based score (47.90). Neutral responses regarding challenge pacing, task monotony, sense of achievement, and immersion indicate that player engagement could still be enhanced. Low scores in social interaction were anticipated, given the single-player nature of the game.

We conclude that the game represents a promising supplementary tool for anatomy instruction. Future directions include implementing progressive difficulty levels, introducing new challenges, refining interface clarity, conducting larger controlled studies with objective learning assessments, and performing longitudinal analyses. All game materials are available in the OSF repository.

Declaration of Generative AI and AI-assisted technologies

We used LLMs such as DeepSeek and ChatGPT to improve the article's overall quality. We take full responsibility for all content produced with AI assistance.

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A. Supplementary Material

Supplementary material, such as the questionnaire, the dataset, scripts, game screenshots, gameplay videos, and complementary graphics, can be found at our OSF repository [2].

[2] https://osf.io/fxzcd/overview?view_only=afd91fd8cfa64c7d91cb339661b28ad1