

## 1. AR App Info

EON-XR is an augmented reality (AR) educational application. It aims to encourage users to learn interactively and enhance their learning experience by effectively acquiring information. The application contains various courses, with the one I tried being an animal cell examination course, particularly in biology.

The primary objective of the application is to introduce cells to users in three dimensions. While providing detailed information about the structure and functions of the cell, it offers various teaching tools such as audio explanations, videos, PDF files, images, and three-dimensional content to support the learning process. Additionally, quizzes are provided to assess users' learning levels. Through these quizzes, users can test their learning by activities such as locating a substance within a three-dimensional cell or answering questions.

In the interface of the application as seen in Figure 1 (p. 8) the three-dimensional animal cell is centered, while various buttons are located on the left side. These buttons can be used on touch screens and provide the opportunity to examine the cell in more detail. Users can separate objects, control walking, and use motion-based controls such as navigating the screen or rotating the content through these buttons. At the top, there is a section showing the hierarchy and a section where users can get help. At the bottom, the right side lists activities that can be continued. Users can select the desired activity from this activity list or use the "Next Activity" button to move to the next activity. This arrangement enables users to explore the cell content and complete their learning more effectively.

The time spent by an individual to complete the application varies depending on the complexity of the selected course and the user's learning pace. For the Animal Cell course, it may take approximately 25-30 minutes for an experienced user to complete the entire course, while for someone exploring the application for the first time, learning how the application works and completing the course may take up to 60-70 minutes. The main reason for this longer duration is that the application contains some heuristic problems, which can be explained in the second part.

## 2. Heuristics Evaluation

Heuristics	Explanation of the Problems Add related visuals of problems from screenshots	Propose Solution(s)	Seriousness of each problem. (Low, Middle, High) Why?
Visibility of System Status	1- The problem is the lack of titles or headers describing the contents of the screen, particularly evident when examining the cell. For example, the icons appearing on the left side of the screen (Figure 2, p. 9) lack descriptive titles. This absence of titles or headers presents a significant	To solve this problem, we should consider adding clear titles or headings to every screen, especially for the icons. Prior to beginning the lesson, a short tutorial could be offered, introducing users to each button and its function with descriptive titles. Another option could be integrating tooltips or pop-up text that appears when users	The seriousness of this problem can be classified as High. The lack of descriptive titles or headers significantly impacts user experience and usability, making it challenging for users to comprehend the contents of the screen and navigate through the lesson effectively. Without clear guidance, users may become frustrated and disengaged,

	usability issue as users are required to test each button individually rather than understanding their functions at a glance. Without clear titles, users may struggle to navigate through the lesson effectively, leading to frustration and a suboptimal learning experience.	hover over each icon, providing instant guidance on its purpose without requiring direct interaction.	potentially leading to a negative perception of the application.
	2- The problem is the inconsistency in the placement of menu instructions, prompts, and error messages within the menu interface. For example, when progressing through the lesson sequentially, users cannot see which topic they are currently on (Figure 3, p. 9). This inconsistency disrupts the user experience and makes it difficult for users to locate important information or track their progress effectively.	We should implement a solution that ensures menu instructions, prompts, and error messages are consistently placed throughout the interface. For example, displaying the current topic or lesson progression in a fixed location on the screen, like the top or bottom corner, will make it easy for users to access this information no matter where they are in the menu. Similarly, keeping the placement of other instructional elements, such as prompts and error messages, consistent will help users navigate more smoothly and become familiar with the interface.	Middle. While the inconsistency in placement may not completely prevent users from interacting with the menu interface, it significantly impacts user experience and usability. Users may experience confusion and frustration when attempting to locate important information or track their progress within the lesson, leading to a suboptimal learning experience.
	3- When the user presses the help button on the menu screen, an overlay appears displaying explanations for each menu item(Figure 4, p. 9). However, this overlay covers almost the entire screen, obstructing the user's view of the menu items and making it difficult to navigate.	We should introduce a friendlier help overlay design that offers explanations for menu items without blocking the entire screen. This might include showing tooltips or short explanations beside each menu item, enabling users to access help information while still viewing and interacting with the menu.	Middle. While providing help information is important for user guidance, the current implementation disrupts the user experience by obstructing menu navigation. Users may find it frustrating to have their view obstructed while trying to interact with the menu, leading to potential usability issues.
	4- The problem lies in the use of a non-attention-grabbing color, such as white, for elements like navigation buttons (e.g., "Next" button) or menu sections within the system(Figure 5, p. 10). These elements fail to stand out prominently against the background or surrounding content, making them less noticeable to users. As a result, users may overlook these important interactive	To solve this problem, we should use more eye-catching colors for important interactive elements like navigation buttons and menu sections. Bright and contrasting colors, such as vivid blues or greens, can effectively attract users' attention to these elements. Additionally, incorporating visual cues like icons or hover effects can further improve the visibility and usability of these interactive parts.	Low. While the use of a non-attention-grabbing color may slightly impede the efficiency and usability of the system, it is unlikely to prevent users from accessing essential functions. Users may experience minor inconvenience or momentary confusion, but it is not expected to result in a significantly negative overall user experience.

	elements, leading to difficulties in navigating through the system or accessing menu options effectively.		
	5- The problem arises from the lack of contrast between the subtitles and the background in the video section(Figure 6, p. 10). The subtitles consistently appear in white text, making them difficult to read when displayed against a light-colored or bright background. This lack of contrast reduces the legibility of the subtitles and may render them unreadable to users, particularly in scenes with bright lighting or light-colored backgrounds.	To solve this issue, we should improve the contrast between the subtitles and the background. One way to do this is by adding a slightly transparent background behind the subtitles to make them easier to see and read. Additionally, using a different text color that contrasts well with the background, like black or a dark shade, can enhance readability on different backgrounds. Another option is to let users adjust the subtitle display settings, including the text color and background transparency, to match their preferences and viewing environment.	Middle. While the issue may not directly prevent users from accessing or using the video content, it significantly affects the user experience by impairing the readability of subtitles. Users may struggle to understand the dialogue or narrative of the video, leading to frustration and a diminished viewing experience, particularly in scenarios where subtitles are essential for comprehension.
	6- The problem lies in the persistent display of the control indicator at the bottom of the video player for approximately three seconds whenever the video is paused or resumed(Figure 7, p. 10). This control indicator overlaps with the area where subtitles are displayed, causing users to miss approximately three seconds of subtitle content each time the indicator appears. This interruption disrupts the user's ability to read subtitles and follow the video content seamlessly.	We should adopt a solution that allows users to dismiss the control indicator themselves. One option is to let users simply tap or touch the video screen briefly to immediately remove the control indicator. This way, users can quickly access the subtitle content again without any interruption and continue watching uninterrupted.	Low. The persistent display of the control indicator at the bottom of the video player (Figure 7, p. 10) interrupts subtitle viewing when the video is paused or resumed. While this interruption affects the user experience by causing users to miss subtitle content, it doesn't completely prevent them from accessing or understanding the video. Implementing a user-controlled mechanism to dismiss the indicator would improve the viewing experience, but the current issue doesn't pose a significant usability barrier.
Match Between the System and the Real World	1- The problem arises from the icons not being concrete and familiar to users. Some icons lack clear visual representations of their intended meaning, making it difficult for users to understand their functionality at a glance(Figure 2, p. 9). This lack of familiarity and ambiguity in iconography can lead to user confusion and	To solve this problem, one option is to include text labels alongside icons or use text instead of icons altogether. This ensures that users can understand the function of each element easily without relying solely on visual cues. Alternatively, if icons are necessary, redesigning them to be more recognizable and adding tooltips that offer extra context when users hover over them can improve their usability and	High. The problem stemming from the unfamiliarity and ambiguity of icons greatly undermines user experience and usability within the interface. When users encounter icons lacking clear visual representations, they often experience confusion and frustration, significantly impeding their ability to complete tasks efficiently. Additionally, the absence of clear textual labels alongside icons

	uncertainty when navigating the interface.	understanding.	presents substantial accessibility challenges, particularly for users with visual impairments. This issue not only diminishes the effectiveness of the interface but also contributes to a notably negative overall user experience.
	2- The problem is that all button colors have been set to white(Figure 1, p. 8). This design choice deviates from common expectations about color codes, where certain colors are often associated with specific actions or meanings. As a result, users may not intuitively recognize the purpose or importance of different buttons, hindering their ability to navigate the interface effectively.	We should implement a solution that utilizes color codes aligned with common expectations to help guide users towards their intended actions. For instance, buttons for crucial or primary actions, like the "next" button, could be colored in a distinct and attention-grabbing hue, such as green. This color choice signals to users the importance of these buttons and prompts them to take action. Also, maintaining consistency with established color conventions can assist users in quickly grasping the purpose of various interface elements.	Low. While the uniformity of button colors may have a minor impact on user experience and usability, it is unlikely to completely deter users from interacting with the interface. Although users might experience some confusion regarding the function or significance of different buttons, this is unlikely to substantially impede their ability to navigate the interface or accomplish tasks. Therefore, although the issue could be improved, it does not present a critical obstacle to usability.
User Control and Freedom	1- Users are unable to rewind or fast forward audio content within the application(Figure 8, p. 11). This limits their control over the playback experience and can lead to frustration, especially when trying to navigate through longer audio segments.	We should incorporate standard audio playback controls like rewind and fast forward buttons or a timeline scrubber to enable users to navigate through audio content effortlessly. These controls need to be clearly visible and easy to use for the users.	Low. Although the absence of audio playback controls may inconvenience users, it doesn't critically impede their interaction with the application. While users might face minor challenges in navigating audio segments, alternative methods like manual scrubbing remain available. Therefore, while adding playback controls would enhance the experience, their absence doesn't present a major usability issue.
Consistency and Standards	1- The problem is the lack of the use of high-value, high-chroma colors to attract attention within the interface(Figure 5, p. 10). All buttons in the interface are of the same color, namely white. This uniformity in color fails to effectively draw attention to important elements or actions within the interface. As a result, users may have difficulty identifying interactive elements or distinguishing between different types of	We should adopt a solution that utilizes high-value, high-chroma colors for significant elements or actions. Employing vibrant colors that contrast with the background can effectively draw users' attention to key interactive elements like buttons or calls to action. For instance, primary action buttons could be emphasized with bold colors such as red or blue, while secondary buttons could be displayed in a contrasting color to indicate their lower priority. This color contrast would facilitate users	Low. The uniform use of white color for all buttons in the interface (Figure 5, p. 10) doesn't effectively highlight important elements or actions. While it may cause some difficulty in identifying interactive elements, users can still navigate through the interface. Although adding vibrant colors could improve visual clarity, the current color scheme doesn't pose a major usability issue.

	buttons, leading to confusion and a suboptimal user experience.	in identifying and engaging with important elements on the interface.	
Error Prevention	1- The problem involves error messages failing to adequately inform the user of the severity of the error and suggest the cause of the problem. In scenarios where the user submits incorrect text, such as typing "Golgy Comleks" (Figure 9, p. 11) instead of "Golgi Complex" or "Nucleus" (Figure 10, p. 11) the system treats both errors as equally severe and provides the same generic error message. However, there is a significant difference between making a simple typographical error and providing entirely incorrect information. The lack of distinction in error messaging fails to convey the severity of the error or provide guidance on how to rectify it, leading to user confusion and frustration.	A solution involving the implementation of informative error messages that differentiate between error severity and suggest the cause of the problem should be adopted. When users submit incorrect text, the error message should provide specific feedback tailored to the nature of the error. For instance, if the error is due to a simple typographical mistake, the message could indicate that the input contains spelling errors and suggest corrections. Conversely, if the error is due to providing entirely incorrect information, the message could indicate that the input does not match the expected content and provide guidance on what the correct input should be. This approach helps users understand the nature of their error and how to correct it effectively.	High. The lack of informative error messages significantly impacts user experience and usability, as it hinders users' ability to understand and address errors effectively. Without clear guidance on the severity and cause of errors, users may struggle to correct their mistakes, leading to frustration and a reduced likelihood of successful task completion. Additionally, providing generic error messages can undermine user confidence in the system's reliability and effectiveness.
Recognition Rather than Recall	1- The problem stems from the absence of subtitle-like text for displaying spoken words during 3D playback. Unlike in video and audio content where users have the option to view subtitles or captions, this feature is lacking in the context of 3D playback (Figure 11, p. 12). As a result, users are unable to access textual representations of spoken dialogue, which may hinder their comprehension of the content, especially in scenarios where audio clarity is compromised.	A solution involving the implementation of subtitle-like text for spoken words during 3D playback should be adopted. Users should be provided with the option to enable subtitles or captions that display the dialogue spoken during the 3D playback. This can be achieved by integrating a subtitle toggle button or menu option into the 3D playback interface, allowing users to turn on or off the display of spoken words as text overlays.	Middle. While the absence of subtitle-like text may not prevent users from accessing or engaging with 3D playback content entirely, it significantly impacts user experience and comprehension. Users who rely on textual representations of spoken dialogue, such as those with hearing impairments or those in noisy environments, may struggle to understand the content without this feature, leading to frustration and reduced satisfaction.
	2- The problem arises from the lack of functionality in the PDF section, where clickable links do not redirect users to the intended pages when clicked(Figure 12, p. 12). Despite the presence of	We need to implement a solution that enables clickable links within the PDF. Users should be able to directly access linked pages by clicking on embedded links within the PDF document. This can be achieved by ensuring that the PDF	Low. Clickable links within the PDF section (Figure 12, p. 12) are not functional, requiring users to manually copy and paste link addresses into a separate browser window. While this disrupts the browsing experience, it doesn't

	clickable links within the PDF, users are unable to navigate to the linked pages directly by clicking on them. As a result, users are required to memorize or manually copy the link addresses and paste them into a separate browser window to access the linked content, which disrupts the seamless browsing experience.	viewer application or platform supports clickable links and enabling this feature for all PDF documents containing hyperlinks.	prevent users from eventually accessing the linked content. Although implementing clickable links would improve workflow efficiency, the current issue doesn't pose a significant usability barrier.
Flexibility and Efficiency of Use	1- The problem is the inability to adjust the playback speed of the video in the video section (Figure 13, p. 12). Users are restricted to only one playback speed, typically the default speed, without the option to increase or decrease it according to their preference. This limitation deprives users of the flexibility to control the pace of video playback, hindering their ability to consume content at their preferred speed.	To resolve this issue, we should implement playback speed controls. Users should have the ability to adjust the video playback speed according to their preferences. This can be done by adding playback speed buttons or a slider control to the video player interface, allowing users to increase or decrease the speed as needed.	Low. Users are unable to adjust the playback speed of videos in the video section (Figure 13, p. 12), limiting their ability to consume content at their preferred pace. While this limitation impacts user experience by depriving users of flexibility in video playback speed, it doesn't completely prevent them from accessing or viewing the content. Implementing playback speed controls would enhance the user experience, but the current issue doesn't pose a significant usability barrier.
	2- The problem arises from the lack of ability to adjust the playback speed of audio content (Figure 8, p. 11). Users are unable to control the speed of audio playback, whether they want to listen to it slower or faster. This limitation restricts users' flexibility in consuming audio content according to their preferences and needs.	To address this issue, a solution involving the implementation of playback speed controls for audio content should be adopted. Users should be provided with options to adjust the playback speed, allowing them to listen to the audio content at a slower or faster pace. This can be achieved by integrating playback speed buttons or a slider control into the audio player interface, similar to those used in video players.	The seriousness of this problem can be classified as Middle. While the inability to adjust playback speed may not prevent users from accessing or listening to the audio content, it significantly impacts user experience and engagement. Users who prefer to consume content at a different pace than the default speed may find the lack of control frustrating, leading to reduced satisfaction and potentially discouraging them from using the audio feature altogether.
	3- The problem arises from the inability to select and copy text within the PDF section(Figure 12, p. 12). When users attempt to copy a word or sentence from the PDF, they are unable to perform text selection, preventing them from copying the desired text for further use or reference. This limitation inhibits users from extracting	To address this issue, a solution involving the implementation of text selection functionality within the PDF viewer should be adopted. Users should be provided with the ability to highlight and select text within the PDF document, enabling them to copy and paste the desired content for their purposes. This can be achieved by ensuring that the PDF viewer application or platform	Middle. While the inability to select and copy text within the PDF may not prevent users from accessing the information altogether, it significantly hinders user experience and productivity. Users may encounter frustration and inconvenience when they are unable to extract specific information or quotes from the PDF content for their work or research purposes,

	specific information from the PDF content, hindering their ability to interact with and utilize the information effectively.	supports text selection and enabling this feature for all PDF documents.	potentially leading to a negative perception of the platform or application.
Aesthetic and Minimalist Design	1- The problem is the absence of "find next" and "find previous" shortcuts for database searches within the system(Figure 5, p. 10). These shortcuts are essential for users to efficiently navigate through search results and quickly locate relevant information. Without these shortcuts, users may need to manually scroll through search results or repeat search queries to find the desired information, resulting in a slower and less efficient search process.	To tackle this problem, we should implement shortcuts for database searches, such as "find next" and "find previous." These shortcuts would let users navigate through search results sequentially, moving to the next or previous occurrence of their search query with a single keystroke or click. This would streamline the search process, helping users locate information more quickly and efficiently.	The seriousness of this problem can be classified as Middle. While the absence of "find next" and "find previous" shortcuts may not prevent users from conducting database searches altogether, it significantly impacts user experience and productivity. Users may experience frustration and inefficiency when navigating through search results, leading to a suboptimal search experience and potentially hindering their ability to find the desired information in a timely manner.
Help Users Recognize, Diagnose, and Recover from Errors	1- The problem is with the assessment of whether each icon stands out from its background, particularly in the AR section(Figure 5, p. 10). Due to the variability in background brightness or darkness in the AR environment, some icons may not be clearly visible or easily distinguishable from their surroundings. This inconsistency in icon visibility can lead to difficulties in identifying and interacting with icons, potentially hindering user navigation and interaction within the AR environment.	To solve this problem, we should implement consistent and effective strategies to ensure icons are visible in the AR section. One approach is to use icon designs with contrasting colors or outlines to make them stand out prominently against different background conditions. Additionally, adjusting brightness or contrast based on the lighting conditions of the AR environment can enhance icon visibility and ensure they remain clear regardless of background brightness or darkness.	The severity of this issue should be classified as High. Although visibility problems with icons in the AR section may not entirely prevent users from navigating or interacting with the application, they significantly impact user experience and usability. Users may encounter frustration and difficulty in locating and interacting with icons, leading to a suboptimal AR experience and potentially discouraging further engagement with the application..
Help and Documentation	1- The problem lies in the difficulty of finding information within the navigation system, particularly when attempting to access specific items within the cell (Figure 3, p. 9). The proximity of items to each other makes it challenging for users to precisely select the desired item with their fingers.	To tackle this problem, we need to improve the navigation system. Firstly, increasing the spacing between items within the cell can reduce accidental selections and make it easier for users to accurately choose the desired item. Additionally, adding a search function that lets users search for items by name can significantly	Middle. While the difficulty in precisely selecting items and the lack of a search feature may not completely prevent users from accessing information, they significantly impact user experience and efficiency. Users may experience frustration and inefficiency when attempting to navigate and locate specific items within the application,

	Additionally, there is no guidance or search functionality available to assist users in locating specific items by name. These issues hinder users' ability to efficiently navigate and locate information within the application.	improve navigation. This search feature should offer predictive suggestions and instant feedback as users type, making item retrieval quick and precise.	leading to a suboptimal user experience and potentially discouraging further engagement with the application.
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4. References

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5. Appendices

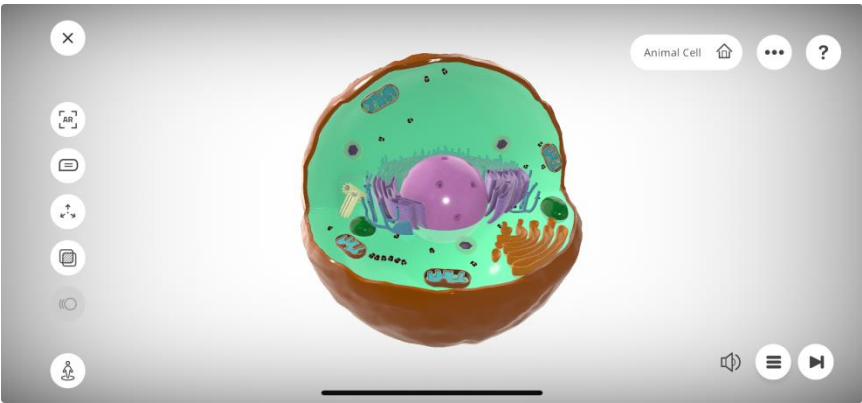
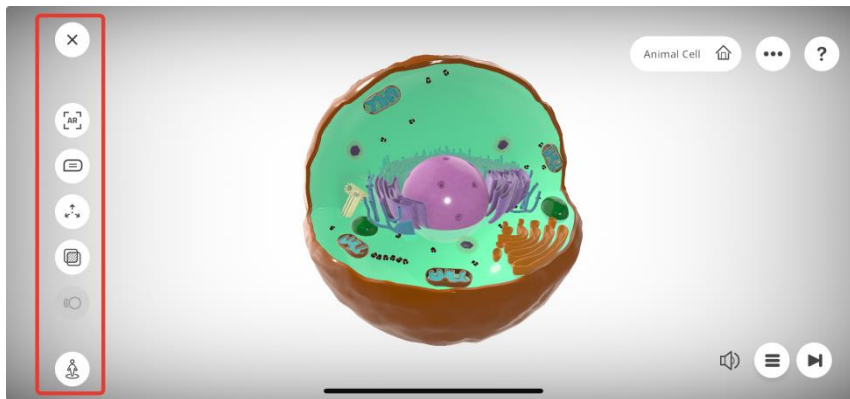
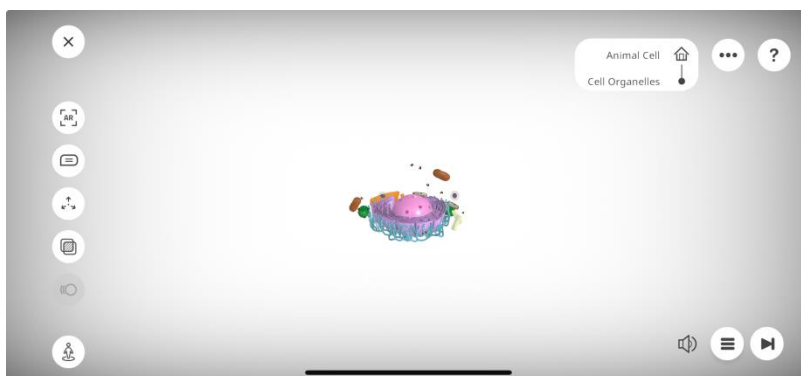


Figure 1 - Interface of the application

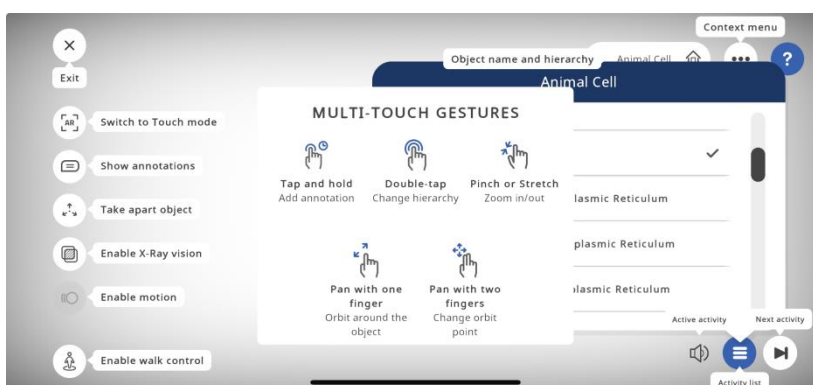




*Figure 2 - Icons Without Descriptive Titles*



*Figure 3 - Inconsistent Placement of Menu Instructions*



*Figure 4 - Overlapping Help Overlay*



Figure 5 - Non-Prominent Navigation Buttons and AR Background Problems

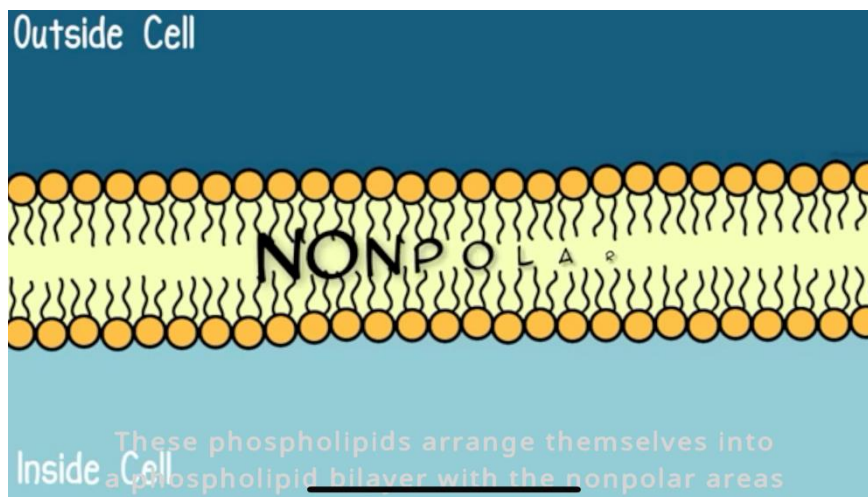


Figure 6 - Subtitle Visibility Issue

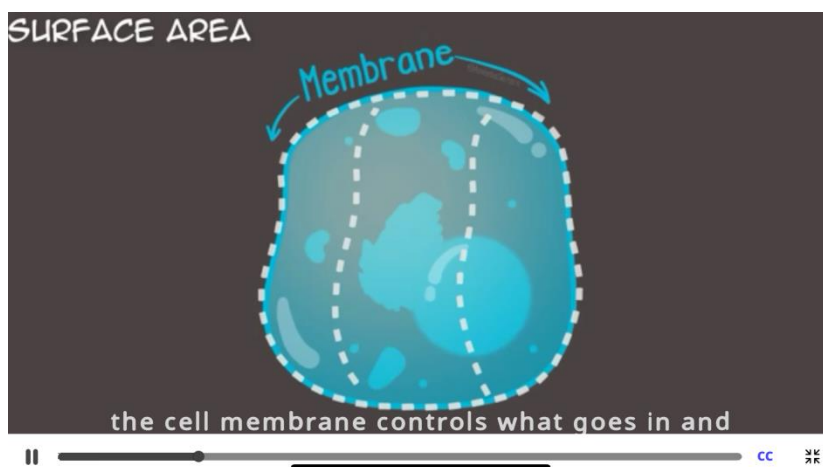


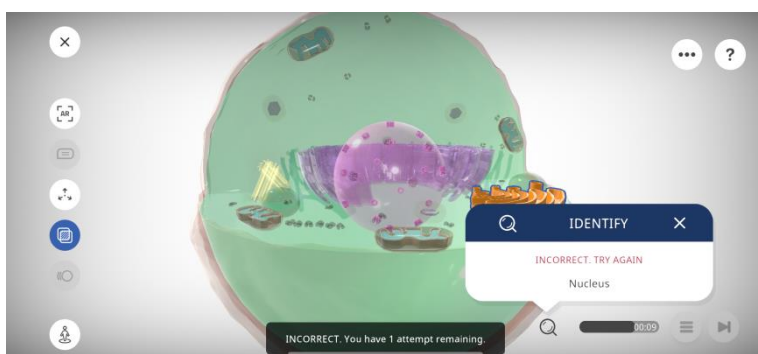
Figure 7 - Persistent Control Indicator Interruption



*Figure 8 - Lack of Audio Content Playback Control*



*Figure 9 - Inadequate Error Messaging for Typographical Errors( Golgy Complex)*



*Figure 10 - Inadequate Error Messaging for Typographical Errors( Nucleus)*

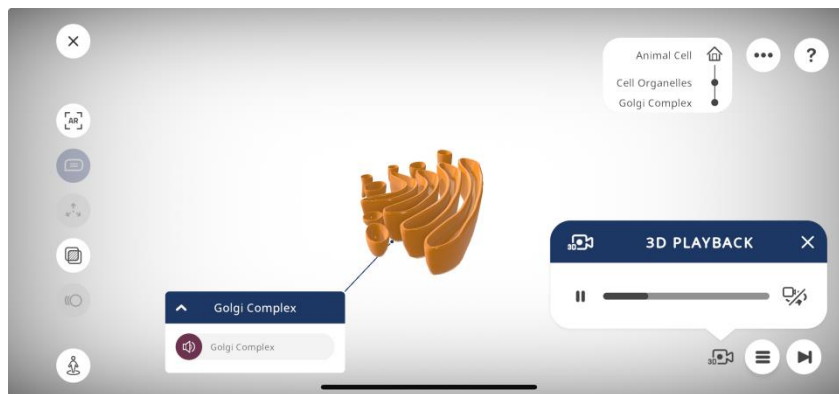


Figure 11 - Lack of Subtitle-Like Text for 3D Playback

- Phospholipids can be synthesized in an abiotic environment without enzymes now
- Phospholipid bilayers now make up the plasma cell membranes that regulate movement into and out of prokaryotic and eukaryotic cells.

**A**

**B**

Single chain lipid

Phospholipid

<http://clincancerres.aacrjournals.org/content/11/5/2018/F1.expansion>

<http://web.nestucca.k12.or.us/nvhs/staff/whitehead/homework.htm>

Figure 12 - Non-functional Clickable Links in PDF Section

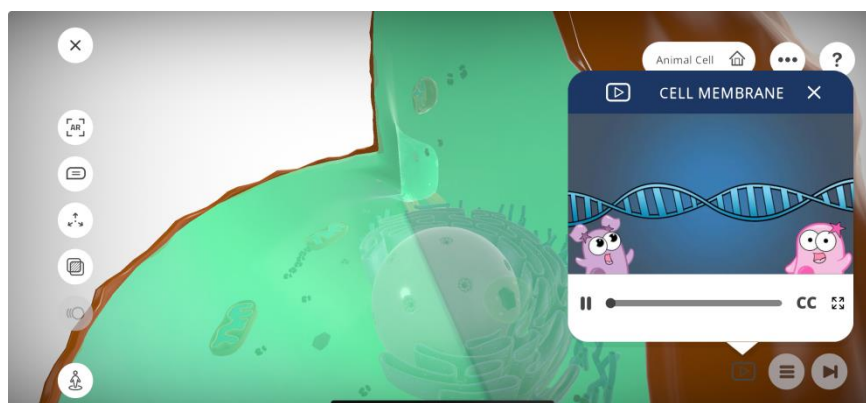


Figure 13 - Inability to Adjust Video Playback Speed

