A constructivist approach to e-text design for use in undergraduate physiology courses

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Rhodes AE, Rozell TG. A constructivist approach to e-text design for use in undergraduate physiology courses. Adv Physiol Educ 39: 172–180, 2015; doi:10.1152/advan.00011.2015.—Electronic textbooks, or e-texts, will have an increasingly important role in college science courses within the next few years due to the rising costs of traditional texts and the increasing availability of software allowing instructors to create their own e-text. However, few guidelines exist in the literature to aid instructors in the development and design specifically of e-texts using sound learning theories; this is especially true for undergraduate physiology e-texts. In this article, we describe why constructivism is a very important educational theory for e-text design and how it may be applied in e-text development by instructors. We also provide examples of two undergraduate physiology e-texts that were designed in accordance with this educational theory but for learners of quite different backgrounds and prior knowledge levels.

THE NATURE OF TEXTBOOKS in college courses is changing as mobile learning rises worldwide. Using the United States as an example of this increasingly global phenomenon, the number of devices owned by the average American college student is noteworthy and reflects shifts in student preferences for information acquisition. For example, the average American college student owns approximately seven internet-ready devices, with the percentage of students defining their most important device for academic activities as follows: 85% personal laptop, 45% tablet PC, 37% smartphone, and 31% e-reader (6). It appears that the use of tablets and smartphones by students for academic activities is increasing dramatically, as one study (6) found the use of these devices to have doubled between 2012 and 2013. In response to this trend, textbook publishers have begun offering more texts in digital formats, and the adoption of digital texts (e-texts) is projected to grow exponentially (39). In addition, many software packages exist that allow individual instructors to create and distribute their own e-texts. As a result, e-texts are poised to become the dominant format in college materials in the next decade, relegating traditional printed textbooks to a supporting role. Simply put, e-texts and college materials in the next decade, relegating traditional printed texts (12, 39). These issues are exacerbated when the use of these devices in undergraduate physiology courses; very few studies have focused specifically on the challenges of teaching and learning with e-texts in this subject (43). The few studies on e-texts in undergraduate courses have primarily focused on education, psychology, and business courses, and almost all were conducted in an educational laboratory setting instead of assessing e-text use in a real course setting (11, 12). Furthermore, the majority of studies completed thus far have examined the preferences of students and faculty members regarding e-text usage (11, 39); very few have examined the design and development of e-texts through the lens of learning theories. Of the studies completed to date, most have found a few emerging themes regarding student and faculty member preferences for e-texts: they are cheaper and more convenient (11, 29, 39). But what has yet to emerge is a deeper collection of themes such as e-text design and development that is theory driven, subject specific, and helps explain the interactions learners have with this form of educational technology (10, 12, 30, 39, 42).

Contributing to the unknowns about e-text usage in undergraduate physiology courses is the dearth of literature describing best practices for instructors to consult when implementing an e-text into their course. The transition from a commercially produced, one-size-fits-all textbook to an e-text requires careful consideration. For example, the time commitment for content development, the availability of an online learning platform for e-text distribution to current students, as well as the decision to license the final product for global online distribution via creative commons should all be evaluated.

One solution for meeting the challenges associated with e-text adoption is the creation of an e-text specifically designed for a particular course by the instructors themselves. After careful consideration, this was the approach taken by the authors as detailed in the present article. Advantages to creating a course-specific e-text include the ability to tailor information to a specific group of students based on their level of academic preparation, the inclusion of examples that are ex-
e-Texts are the digital media equivalent to printed texts (29). e-Texts comprise a digital body of content that has a defined scope (17). e-Texts can be downloadable or Web based and viewed using a computer, e-reader, tablet, or smart phone. In addition, e-texts can be printed and used in a more traditional way (29).

e-Texts may or may not require a direct internet connection for access and use. However, knowing the level of internet accessibility of the end-user is helpful when designing an e-text. For example, an e-text containing only text and static images such as pictures and tables can be downloaded from the internet and viewed offline using a variety of applications. This provides the ultimate level of portability but limits the features that can be included in the e-text, such as interactive multimedia and embedded quizzes. To accommodate an e-text with these features, a direct internet connection is usually required. The only exception to this entails the use of online “bookstores” such as iBooks. e-Texts containing interactive media and quizzes that are available and downloaded via the iBooks application are self contained, meaning the media and interactive features are downloaded with the e-text and stored on the user’s device, permitting full use even if internet access is not available.

e-Texts generally exist in two formats: page fidelity e-texts and reflowable digital e-texts (30). Page fidelity e-texts are exact copies of a printed text but have been scanned and exported as a PDF, allowing them to be distributed and accessed on the internet. This results in large file sizes and the inability of some internet-ready devices to read them. Page fidelity e-texts can be slow to open and difficult to navigate as scrolling is often cumbersome. In addition, annotative features such as highlighting and note taking are often not permitted. As a result, learners do not prefer this format of e-texts compared with traditional textbooks (42). Furthermore, because page fidelity e-texts are simply electronic copies of traditional printed texts, they are not designed with appropriate educational theories regarding learning from digital materials. Many confounds exist when educational media are designed for one delivery mode (traditional print) yet offered in another mode (digital format), and learning can be impacted by both the format of the text and the medium through which it is offered (30, 38). It is possible that the lack of appropriate theory-driven design and development has led to inconclusive results from studies that have examined the use of these types of e-texts in regard to learner preferences, instructor preferences, and improvements in comprehension and retention (3, 19, 25, 32, 36). Because of these factors and also because page fidelity e-texts are not likely to have much role in future e-text development, we will focus on reflowable e-text design for the remainder of this article.

Reflowable e-texts are designed specifically for Internet-ready devices and facilitate a greater number of features, such as interactive media, embedded quizzes, hyperlinks, and annotation. In addition, reflowable e-texts are designed for optimal viewing regardless of the internet-ready device used to access them. Reflowable e-texts and the interactive features they contain are preferred due to the enhanced learning capabilities this format can potentially provide and the ability to align the development of these e-texts with current learning theories related to the use of digital learning tools.

e-Texts Are Poised to Become the Dominant “Book” Format

Since 2011, e-book sales have outsold printed books on Amazon.com and continue to grow through the marketplace (12, 24, 26a). e-Book circulation in public libraries is also growing; for example, e-book circulation increased by 85% in 2013 compared with 2012 (41). It is quite possible that e-texts will follow this trend as more become available, student familiarity increases, and federal and state educational mandates are updated (11). According to President Obama, every student in the nation should have an all-digital curriculum by 2017 (31).

e-Texts can provide multiple benefits to learners that go beyond what is afforded by traditional texts. For example, e-texts offer superior flexibility, accessibility, and convenience, can be customized based on student and instructor preferences, are far less costly, and can facilitate numerous interactive features (1, 4, 5, 8, 9, 11, 12, 21, 26). In addition, e-texts can be designed to provide assistance to students with learning disabilities or physical disabilities. Known as “assis-
tive technology” or “supported e-texts,” these e-texts permit the modification of many features to suit the needs of the user; these have been shown to increase reading comprehension (1). For example, text size, font, and color can be altered, text can be read aloud, concepts can be defined and explained, multiple illustrations can appear simultaneously, and hyperlinks can be embedded (1).

Despite these capabilities, the majority of e-texts currently available to students are largely digital copies of traditional print texts (11, 42). While most have incorporated a reflowable design for accelerated downloading and scrolling, few have fully embraced the interactive features that could quite possibly allow e-texts to reach their potential as a learning tool (30). Furthermore, e-texts developed by publishing companies are generally designed and developed for a broad audience, just like traditionally printed texts. This one-size-fits-all approach oftentimes fails to facilitate the specific needs of students, resulting in reduced learning gains.

However, due to the number of authoring software packages that now exist, educators can create their own e-texts and possibly avoid the confounds that exist when using commercially produced e-texts from publishing companies. The benefits of doing so are numerous, but perhaps the greatest benefit comes from no one being more acutely aware of what students need than the instructors who interact with them on a daily basis. We encourage educators to consider developing e-texts for their own courses, matching format and content to the specific needs of their students. What follows is a theoretical framework for accomplishing this.

Relevant Learning Theories for e-Text Construction/Theoretical Framework

E-texts, like other forms of digital curriculum materials, must be constructed in accordance with specific learning theories if they are to be effective. Learning theories provide verified instructional guidance for facilitating learning as well as a foundation for intelligent strategy selection for effective instruction (14). However, pinning down the right educational theory when designing and developing an e-text is not simple. Theories that have been traditionally used for the development of curricular materials, such as behaviorism and cognitivism, do not adequately accommodate the potential capabilities offered by digital materials nor the needs of current and future students. Behaviorism is defined as the science of behavior where appropriate training should elicit a correct and measurable response. In education, behaviorism entailed the use of techniques that were designed to create appropriate conditioned responses in the learner due to improved morale and heightened interest (35). Cognitivism focused on the storage and retrieval of information and encouraged the practicing and rehearsing of information to improve retention. Measurable changes in outward behavior were central tenets of cognitivism and viewed as a sign that learning had occurred (16, 23).

However, neither of these theories accommodates the speed at which information is now available to students nor offers guidance on preparing students for future challenges to be encountered in jobs that do not even exist at this time. For example, as little as 40 yr ago, students would complete a set amount of required schooling and enter a new career that would often last a lifetime. Information development and distribution was slow. The life of information and the knowledge it led to was measured in decades. Today, however, the lifespan of information is measured in single years, or perhaps even months. This was true more than a decade ago, when Gonzalez (15) warned:

Technology is placing unique requirements on people in the workplace, compelling a sharp focus on training and education. One of the most persuasive factors is the shrinking half-life of knowledge. The ‘half-life of knowledge’ is the time span from when knowledge is gained to when it becomes obsolete. Half of what is known today was not known 10 years ago. The amount of knowledge in the world has doubled in the past 10 years and is doubling every 18 months according to the American Society of Training and Documentation.

Given the half-life of knowledge, the goal of education and design of curricular materials to support education have also had to change. The target for effective instruction has shifted away from the memorization of facts for recall at a later date and toward the development and refinement of students’ cognitive processes that allow them to review and assess vast amounts of information, decide which bits are useful, and then construct meaning from these bits to solve a larger problem—a problem that quite possibly does not even exist today.

Thus, the design and development of curricular materials, especially digital materials such as e-texts, must accommodate these new challenges. Not only must these materials serve as a source of accurate and up-to-date information, but also foster the development of students’ cognitive architecture, which allows them to select relevant bits of information, connect these bits together to produce a more complex concept, and then apply that concept to a novel situation. Providing insight and guidance for meeting these challenges is the learning theory known as constructivism.

Constructivism

Constructivism is an important and driving theory of learning in modern education, especially science, technology, engineering, and mathematic (STEM) education (2). However, this theory is often misused; activities and materials claiming to be constructivist in nature often fail to adhere to the supporting principles. This likely occurs because constructivism can be hard to define and use. Furthermore, the literature on constructivism is often theoretical and provides little connection between theory and practice, especially for use in STEM courses, or provides descriptions of constructivist supported activities but fails to bridge the gap between the activity and the theory (2).

Constructivism is a theory of learning and not of curriculum design (2, 28). Thus, when a lesson is said to be constructivist, it does not necessarily follow a specific formula. Instead, constructivism provides critical guidance on the design and development of activities and materials that create the greatest opportunities for students to learn difficult information, retain that information, and apply it at a later date and even to a novel problem. Exactly how a constructivist approach plays out in a specific classroom or course depends on content domain, the age of the learners, prior experiences of learners with the content to include both formal and informal, and the atmosphere of the course, which includes the teaching style of the instructor (28). In other words, implementation of constructivism is the crux of the theory (2), and successfully implement-
ing any constructivist-based lesson or designing any constructivist-based learning tool depends almost exclusively on the type of learner that will be receiving the lesson or using the tool. A one-size-fits-all approach is the antithesis of constructivism. For example, the central tenet of constructivism states that knowledge possessed by a learner is connected in a comprehensive construct of facts, concepts, experiences, emotions, values, and their relationship to each other. If a learner’s set of constructs is insufficient compared with the information with which he or she is being presented, a form of cognitive dissonance will occur due to a misalignment between the learner’s previously held beliefs about a concept and the new, more complex information being presented. At this point, the learner must make a decision: reject the new information or incorporate it into his or her personal construct. To make any permanent changes to the knowledge construct, the learner must be able to apply the changed construct to novel situations, receive feedback about the validity of the construct from a more knowing other such as a more advanced peer or instructor, and establish further connections to other elements in the construct (2, 20).

The benefit of this approach to learning may not be directly observable via traditional assessment techniques as the transformation that can occur regarding a learner’s approach to and interaction with the material may require months or even years. To adequately measure the effectiveness of a constructivist approach would require following the learner for an extended period of time and evaluating how his or her approach to learning has changed. This is the challenge of creating an effective e-text via a constructivist approach to learning. Unlike more traditional methods such as behaviorism and cognitivism, where transmission of information is one of the most important aspects of design and can be measured with the use of student assessments and quantitative analyses, constructivism does not often include such analyses. According to Richardson (28):

It is important to note that an empirical focus on the relationship between teaching and student learning does not necessarily require an experimental study that compares constructivist and traditional instruction. Such an experimental design might be helpful for policy purposes, but agreement on the outcomes of instruction would be difficult to achieve.

In an effort to make the central tenets of constructivism more relevant for use in college courses, specifically for the development of curricular materials such as e-texts, Table 1 shows

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<tr>
<th>Constructivist Criteria</th>
<th>Description</th>
<th>Examples of Use</th>
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<tbody>
<tr>
<td>Learner centered</td>
<td>Create context where learner is motivated to learn; includes presenting content that is relevant, posing concepts, problems, and questions at appropriate times based on the background and previous experiences of the learner with the specific content domain (28).</td>
<td>Precursor to e-text development; requires background information about students enrolled in a course such as career goals, experience with subject in the past, and motivational and self-efficacy factors.</td>
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<td>Integration with prior knowledge</td>
<td>All knowledge is acquired in relation to prior knowledge of learner; if prior knowledge is not elicited, new knowledge cannot be gainfully presented in a way that can be incorporated into the learner’s construct; as a result, the learner will either ignore or incorrectly incorporate the new knowledge (2).</td>
<td>Scaffold content to support prior knowledge of learners; low prior knowledge learners require more instructional support in the form of highly structured content, definitions and graphics; high prior knowledge learners benefit from less-structured content, less distortions in the form of definitions and graphics, and the addition of novel problems.</td>
</tr>
<tr>
<td>Creation of cognitive dissonance</td>
<td>The learner must be made aware of the gap between current level of understanding and a specific learning goal; this can be accomplished by designing curricular materials that present information residing just outside of learner’s current state of knowledge and provide scaffolding that guide the development of learner’s cognitive architecture such that the learning goal is attained (2, 20).</td>
<td>Inclusion of appropriately structured questions that align with prior knowledge level of learners. Provision of answers also structured in accordance with prior knowledge level of learners; low prior knowledge learners benefit from having worked problems explained in detail with solutions presented step by step, high prior knowledge learners benefit from minimal guidance.</td>
</tr>
<tr>
<td>Application of knowledge with feedback</td>
<td>Misinterpretation and possibly rejection of new knowledge is likely if learner does not interpret and modify prior knowledge in context of new knowledge; application of new knowledge through engagement with tasks that are specifically structured for this purpose are encouraged (2, 28).</td>
<td>Provision of additional activities such as the drawing of structures and relationships or use of multimedia that presents a case study vignette encourages direct application of new knowledge and fosters group discussions allowing learners to challenge, change, or add to existing beliefs in light of what peers believe.</td>
</tr>
<tr>
<td>Reflection on learning</td>
<td>Development of learners’ metawareness or metacognition of their own understanding of a concept (28)</td>
<td>Return to dissonance-creating activity; evaluate progress with assessments such as embedded quizzes.</td>
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five essential criteria that must be included and examples of how to apply these criteria.

Examples of e-Texts Designed for Undergraduate Physiology Courses

Given the proposed place e-texts will have in education and their potential to increase student learning gains coupled with the complex nature of concepts taught in undergraduate anatomy and physiology courses and the frequent turnover of information, e-texts hold great potential as a useful teaching tool for this discipline. However, it is surprising that after an extensive search on e-text design and development for undergraduate physiology courses it appears that instructors interested in designing their own e-texts are left with either using other unrelated disciplines as models or must set out on their own. We present two e-texts designed in accordance with the criteria of constructivism and specifically for learners of low and high prior knowledge in two college anatomy and physiology courses. Students use the e-texts before, during, and after lectures and laboratories. For example, before each class, students are advised to complete a particular reading and define pertinent vocabulary. During class, students use the open or blank drawing fields to participate with the instructor as concepts are mapped, drawn, and labeled. This can be done directly into the e-text with the use of a stylus (if using a tablet computer) or with markers or colored pencils (if using a printed version). After each class, students are advised to check their understanding via embedded quizzes, which are tightly linked to preclass readings and in-class drawing activities. At the end of the semester, the result is an e-text that students have helped create for themselves under the guidance of their instructors. This captures the essence of a constructivist approach to learning.

E-text for low prior knowledge learners. This e-text was specifically designed for prehealth students enrolled in a sophomore-level human anatomy and physiology course at a large

![Fig. 1. Examples of presenting and structuring vocabulary in an e-text for low prior knowledge level learners. Definitions were only presented if the word was clicked upon. Mapping the vocabulary words into categories initialized the organization and use of the words in ways that would align with the text.](http://advan.physiology.org/content/176/1/176/F1)

![Fig. 2. Sample of text for low prior knowledge learners; the application of vocabulary words and use of mind mapping was continuous throughout.](http://advan.physiology.org/content/176/1/176/F2)
midwestern land grant university. Students enrolled represented almost every major offered at the university and ranged from sophomores to fifth-year seniors. Career goals and interests were diverse. The one thing that almost all had in common was the lack of any formal experience with this subject at the collegiate level, as indicated by a presemester test. Taking a learner-centered approach to the design of an e-text for this group meant that the text needed to be highly structured and that the creation of schemas, or bits of organized knowledge held in long-term memory, that students developed in response to the information being presented needed to be carefully scaffolded.

The scaffolding of knowledge is analogous to scaffolding used in building construction. In either case, scaffolding is a tool that allows new heights to be reached. With the correct word or question carefully placed or the right educational device used, an instructor puts in place the scaffolding that will allow new knowledge to be constructed, incomplete or incorrect concepts to be challenged or corrected, and forgotten knowledge to be recalled (18).

The first step in structuring and scaffolding the construction of schemas for this low prior knowledge group included the introduction and defining of complex vocabulary words as well as the use of a word map that encouraged learners to organize vocabulary words as they were learned. Learning, organizing, and immediate use of vocabulary words form the foundation of mental schemas (37), and the more schemas that can be constructed, the more learners are likely to retain in college science courses (27). Figure 1 shows a sample vocabulary list and word map from an e-text chapter covering the integumen

Fig. 4. Sample of a completed drawing field. Drawings were an integral part of in-class discussions and allowed concepts described in the text to be presented visually in real time with feedback from the instructor. Students were able to draw directly into their e-text using a stylus and could also make notes in the margin with a note pad feature.
The second step of designing an e-text for the low prior knowledge group was the composition of highly structured text, which continued to encourage the learner to use and apply the vocabulary words previously presented, although in a more applied context. The writing style was simple and concise; complex concepts were broken up or chunked into smaller paragraphs to prevent cognitive overload. Chapters were also chunked into smaller sections with basic and applied questions presented at the end. This design aligned with recommendations provided by Kalyuga (20) for the development of instructional materials for low prior knowledge learners.

The third and fourth steps involved the use of embedded questions that were designed to create an appropriate amount of cognitive dissonance, which was resolved primarily with discussions among students and then with the instructor during class. After discussing the solutions to these questions in detail, students were encouraged to draw the specific structure or process described in the question directly into their e-text; thus, every set of questions was followed by a blank drawing field. This allowed learners to create their own e-text illustrations with direct guidance from the instructor during class.

The fifth and final step of e-text design for the low prior knowledge group entailed embedding interactive quizzes at the end of each section. These quizzes were designed to return the learner to the original dissonance-creating activity or concept; questions were in-depth and required students to connect basic schemas together to correctly ascertain the physiological relationship described.

**e-Text for high prior knowledge learners.** This e-text was specifically designed for students enrolled in a senior-level animal anatomy and physiology course at a large midwestern land grant university. Less academic diversity existed among students enrolled; almost all were students within the College of Agriculture and possessed more similar academic backgrounds and levels of preparation. For these students, a learner-centered approach to e-text design and development meant that a much less structured text would be required. Thus, the inclusion of basic definitions, links, and graphics with detailed descriptions would be contraindicated and perhaps even distracting. Known as the expertise-reversal effect, high prior knowledge learners do not benefit from the same instructional format as low prior knowledge learners (20). The general strategy for tailoring instructions to levels of learner expertise is to gradually replace high-structured content and formats with low-structured content and formats as knowledge levels increase (22).

This e-text paralleled the e-text designed for low prior knowledge learners in that similar components were present. Both e-texts provided an introduction to important terminology, text, level-appropriate questions, drawing fields, and quizzes. However, as shown in Figs. 2-8, the amount of scaffolding used in the e-text for high prior knowledge learners is far less. For example, while a list of important vocabulary words were provided, they were not defined for students. Instead, they were directed to use trustworthy sources to generate suitable definitions, as shown in Fig. 6.

The second step in designing an e-text for high prior knowledge learners was the provision of a more loosely structured text that was primarily intended to supplement more detailed information received during lecture. The removal of extraneous and possibly redundant details is important for increasing learning gains for this group of learners (20).

The third, fourth, and fifth steps involved the inclusion of discussion-generating prompts that were embedded in the e-text. These prompts were designed to foster in-depth discussions among students in the course and, at times, with the instructor. The provision of novel images encouraged students to apply the information gained from these discussions to uncommon issues, reducing redundancy and instilling curiosity. After these discussions, students were encouraged to draw the specific structure or process directly into their e-text; thus, a drawing field followed every set of discussion-generating prompts. This allowed learners to create their own e-text illustrations with feedback from peers and occasionally from
Many animals are protected from harmful ultraviolet radiation by a thick hair coat.

- However, animals may sunburn or get skin cancer in response to exposure to sunlight (particularly UVB and UVC)
- Typically occur in areas where haircoat is thinnest
- Ears, noses, abdomen, genitals
- Cattle, sheep and goats can become more photosensitive when grazing certain green plants
- Causes sunburn like symptoms

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3907879/

the instructor should the amount of cognitive dissonance created remain unresolved after working with peers.

**Student Feedback**

Student feedback received via postsemester teaching evaluations regarding the e-texts designed for the two courses discussed within this article has been positive. Aligning with national trends for e-text usage in United States college courses, students cited the significantly reduced costs and convenience as a major advantage of these e-texts. Additionally, students frequently commented on the use of drawing fields within the e-texts and the benefits of creating visuals in class along with the instructor. Many commented that this helped them maintain focus and contributed to a deeper understanding of concepts.

**Summary**

The purpose of the present article was to provide readers an introduction to the use of e-texts within undergraduate physiology courses as well as an overview of the importance of using current learning theories, such as constructivism, when developing instructional materials. The constructivist approach

![Fig. 7. Sample of loosely structured text designed for high prior knowledge learners. [Sunburned horse: http://extension.udel.edu/equine/tag/sunburn/; sunburned dog: http://www.dognoseprotectors.com/about.html; and dog sunscreen: http://www.dogster.com/dog-health-care/7-sun-safety-suggestions-for-dogs/.]](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3907879/)

![Fig. 8. Sample of discussion-generating prompts intended to foster group discussions among students where creation and resolution of cognitive dissonance should primarily occur. [Lightning-stricken cow: http://www.dailymail.co.uk/news/article-1136542/Pictured-The-cow-zapped-lightning—survived.html; dust mites: http://www.apartmenttherapy.com/dust-and-dust-mite-proof-your-105222/].](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3907879/)
must be learner centered; features and components included must align with the prior knowledge level of the learners enrolled in the course. The results of this approach often yield instructional materials that are different in appearance and function, as illustrated by the two e-text samples provided. However, despite these differences, both e-texts fit the criteria of a constructivist approach to e-text design and development. This article was only intended to provide a theoretical overview to e-text design and development. Further empirical studies examining the effectiveness of specific e-text features, such as the use of interactive multimedia for improved comprehension and retention of information presented in undergraduate physiology courses, need to be conducted.

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