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ARTIFICIAL INTELLIGENCE AND VOICE-POWERED ELECTRONIC TEXTBOOKS AND ELECTRONIC BOOKS

Running head: AI and voice-powered e-textbooks and e-books

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ABSTRACT

Reading, whether as an end in itself as in language arts classes or as a means for learning when done through textbooks, has long been an integral part of classroom education. As much of the information world has moved online, so, too, have books followed. Unfortunately, commercially-available electronic textbooks (e-textbooks) and electronic books (e-books) are typically little more than .pdf versions of their paper counterparts, thus not exploiting other technologies that could be used to increase learning. The present paper describes technologies that use artificial intelligence (AI) and voice/natural language technologies to increase student learning in e-textbooks and e-books. As students learn a lesson, they can verbally ask the technology questions about the content and receive answers much the way they can when using personal assistants on smart phones. When students have completed the material, the technology assesses whether they have learned the material by verbally asking questions and allowing students to answer verbally. Any deficiencies are immediately remediated. When students finish the assessment in the e-textbook, they do practice problems as they would in a standard e-textbook. The difference is that with the present technology, all work is done step-by-step on an electronic worksheet where the underlying AI technology monitors each step and provides hints when requested and feedback when mistakes are made. The present e-textbook technology was tested experimentally by having students either use it or leading publisher Pearson's Algebra 2 Common Core e-textbook to learn division of complex numbers. Students were then given a post-test to measure their learning. Students using the AI and voice/natural language-powered e-textbook scored four times high on the post-test than those using Pearson's e-textbook. The results suggest that AI and voice/natural language technologies can improve educational performance when incorporated into e-textbooks and e-books.

Keywords: A.I., Electronic Books, Students, Learning, Technology

INTRODUCTION

Reading has long been a staple of the educational system. Students read books in language arts classes to enhance their reading comprehension skills and to develop an appreciation of literature. Teachers use textbooks as a basis for their lesson plans and homework assignments. Students read their textbooks to learn basic concepts, which in turn would be reinforced by the teacher in the classroom. Students then dutifully copy their homework assignments from their textbooks onto their notebooks, do their work and turn that work into their teachers for grading. This has been the mainstay of education for much of the past couple of hundred years.

The past generation has seen major changes in the educational system and, indeed, in the world. Much of our information has shifted from paper to electronic/digital format. We go to websites instead of libraries and we read digital newspapers and books instead of paper-based ones. Our sources of digital information have become more ubiquitous and smarter. Cellular phones now double as microcomputers and tap into global networks of information. Technologies such as artificial intelligence (AI) and voice/natural language processing make obtaining information even easier as we can now simply talk to our electronic devices, ask them questions and receive answers about virtually any topic.

Education has slowly made its way into the digital world also as electronic learning (e-learning) platforms have proliferated. Recently, books in general and textbooks in particular have found their way online and many classrooms either supplement or have replaced traditional paper-based textbooks with their electronic counterparts. Unfortunately, as online and other electronic services have been quick to exploit new advances in technology, electronic books (e-books) and electronic textbooks (e-textbooks) have lagged behind, often being little more than .pdf versions of their paper-based counterparts. While such e-books and e-textbooks may provide convenience and resilience compared to their paper-based counterparts, they do little to enhance the effectiveness of the textbook or book as a teaching tool. In fact, a recent study found no difference between paper-based textbooks and e-textbooks in terms of teaching effectiveness

(Laketa and Drakulic, 2015). The study cited e-textbooks' lack of interactivity and their inability to personalize education to the needs of each student.

There have been attempts made in recent years to improve the quality of e-books and e-textbooks. However, often these involve improving the readability of the text rather than improving the teaching value (Gunawan, 2018). Others have focused on factors such as interoperability of content across platforms and lifespan of software tools used to create e-books and e-textbooks (Lokar et al., 2011). A third group has focused on the types of information that e-textbooks should contain (Ivanova and Osmolovskaya, 2016).

While each of these categories of recommendations may very well enhance the user experience of readers who use e-books and e-textbooks, it is unclear how they may improve overall student learning. The present paper is concerned with creating a paradigm shift in how e-books and e-textbooks are constructed, using state-of-the-art technologies such as artificial intelligence (AI), machine learning and voice/natural language processing to produce large enhancements in student learning. The remainder of the paper describes an e-textbook to teach division of complex numbers that was constructed using these technologies. This technology was then compared to a commercially-available e-textbook, Pearson Algebra 2 Common Core--a .pdf-based e-textbook, created by industry leader Pearson to see which version resulted in greater student learning. Our hypothesis is that our AI and voice-powered e-textbook would lead to greater student learning of the material. Also, discussed is an e-book for the story "Little Red Riding Hood" that uses the same voice/natural language technology to reinforce reading comprehension and reader engagement.

Adding Artificial Intelligence and Voice/Natural Language Technologies to Electronic Textbooks.

The goals of adding AI and voice/natural language technologies to e-textbooks are to improve the educational effectiveness of the instruction and to increase the ease of use by making interaction with the e-textbook more natural. Three features that are part of the present e-textbook are discussed.

Querying the E-textbook

While a student goes through the division of complex numbers lesson, he or she has the ability to verbally query the system and receive an answer to his or her question. This is done by clicking on a microphone icon located on the top right part of the screen and then speaking the question. The student's question is translated into text and shown to the student, who can edit it if there is a

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mistake in the speech to text process. Alternatively, the student can type in the question directly instead of speaking it.

Since there are multiple ways to ask a question, the first step of the process is to match the student's question with a question the e-textbook can answer. Semantic similarity calculation is the key process used here. The basics of the semantic similarity calculation is word embeddings. Word2vec is a group of related models that are used to produce word embeddings. These models are shallow, two-layer neural networks that are trained to reconstruct the linguistic contexts of words. With Word2vec technology, we use multiple methods to calculate the semantic similarity between two sentences. The easiest method is the baselines method. This method takes the average of the word embeddings of all words in each sentence and calculates the cosine between the resulting embeddings. The result of the calculation is between 0 to 1. If two sentences are highly similar, the score is closer to 1. For example, the sentence "a man is cutting up a cucumber" has the same meaning as the sentence "a man is slicing a cucumber." The score of these two sentences is 0.97. A similar process is used when a student asks a question. Semantic similarity technology outputs the highest score between the student's question and all the questions in our database. If the score of a question is extremely low (for example, less than 0.15), the student's question may not be a normal sentence. It may be no logical sentence or just repeating words. In this case, our system requests that the student input a more well-structured sentence. If the score of this question is high enough (for example, higher than 0.8), we claim that this question has the same meaning with student's question. If the score of this question is intermediate (for example, more than 0.5 and less than 0.8), the system is not quite sure of the meaning of the student's question. In this case, the system matches the student's question to the question with the highest similarity score that the system can answer. The student is then asked if the matched question is what the student is asking. If the student says yes, the system answers the matched question. If the student says no, the system looks for the next highest match above .5 and asks again. A maximum of three cycles are possible. If the system goes through three matching cycles and finds no match or it cannot find a match with a similarity rating above .5, it assumes it cannot answer the student's question and informs the student of that fact.

Assessing the Student

Following the instruction, the e-textbook assesses the student to see if he or she understood the material. The assessment uses the same voice interface as the querying feature. Students are verbally presented with questions and respond in kind. The system then processes the students' responses and matches them to the underlying knowledge model. If there is a match as described in the previous section, the correct answer is deemed to have been given. If the match is between .5 and .8, the system clarifies what the student stated as described above. If the match is low or

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the student states that the system's interpretation of the student's response is wrong, the system assumes the student gave the wrong answer and corrective feedback is provided.

The assessment queries themselves are derived from an underlying knowledge model of the subject matter to be mastered. The knowledge model is based on the Integrated Knowledge Structure (INKS) framework developed by John Leddo (Leddo, 1994), which combines several knowledge types described in the cognitive psychology literature. These include factual or semantic knowledge (Quillian, 1966), general problem solving plans or scripts (Schank and Abelson, 1977), problem solving procedures or production rules (Anderson, 1982), and causal principles or mental models (de Kleer and Brown, 1981) that explain why procedures are down. Queries are presented to students that are derived from each of these types of knowledge (e.g., "What is i?", "How do you divide two complex numbers?") to assess whether they have a thorough understanding of the subject matter being taught. Our previous research (Leddo and Sak, 1994) found that assessments of student knowledge produced using the INKS framework as their bases correlated .88 with how well students could solve practical problems that use this knowledge.

The Electronic Worksheet

When students finish learning the subject matter and are assessed and remediated if necessary, they proceed to an electronic worksheet where they can do practice problems. This is analogous to the practice problem section of a traditional textbook, with two notable exceptions. First, instead of copying the problems onto a separate sheet of paper and doing the work on that paper, students see the problems on the screen and do the step-by-step problem solving directly on an electronic worksheet supplied by the e-textbook. When this happens, the e-textbook can process the students' step-by-step work and offer hints when requested or corrective feedback to mistakes when made (this is described in more detail below). Second, unlike with a traditional textbook or e-textbook, students can type their own problems onto the electronic worksheet and receive hints and feedback just as what happens when they solve problems taken from the database (the mechanism for this is also described below).

In the present experiment, each question provided to the student involved division of complex numbers of the form (a+bi)/(c+di), where a, b, c, and d are integers. Once the student sees the problem, he or she types in his or her work step-by-step on the electronic worksheet. The worksheet is organized by lines, with one line given for each step. When a student is done typing in a step, he or she clicks on an enter button and the step is evaluated by the AI technology. If the step is correct, the student proceeds to the next step. If the step is incorrect, the worksheet line the step is on is highlighted in yellow and the feedback box explains why the

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step is wrong and how the step should be corrected. When the student completes the problem by entering the correct answer, the students is notified in the feedback box. There is a hint button that students can use. In this case, the hints are tied to the step that the student has recently completed and gives the student information on how to complete the next step. There are three hints available, each at successive levels of detail. For example, in the problems involving division of complex numbers, the general hint tells the students to multiply by 1. The second hint tells the students to try to eliminate the imaginary part of the denominator. The third hint tells the student to multiply by the complex conjugate of the denominator. The actual numbers from the problem are populated into the hint's text.

The hints and feedback capabilities are made possible through AI. The AI component of the system is based on John Anderson's ACT-R framework (Anderson, 1990) that has formed the basis of numerous AI-based instructional systems. The core of ACT-R is a production rule system where sequential procedures are stored based on the antecedent conditions that trigger them. The system then matches the student's input to the step that is listed in the production rule sequence. A match is considered to be a correct step and a mismatch is considered to be an incorrect step. ACT-R allows for more than one pathway to a solution, which is beneficial since there is generally more than one way to solve a problem.

Typically, people who build AI-based systems for education that are modeled after ACT-R enumerate each problem-solving path that is possible for solving the problem. This is done for each specific problem that the system will deliver (cf., Aleven et al., 2006). This becomes particularly cumbersome if the software will ultimately deliver many problems (as would any large scale educational system) or if the system is intended to be flexible enough to allow students to enter their own homework or test-study guide problems as our system allows.

Therefore, in order to create a more flexible system that can support any problem within a problem class, we wrote our system to operate on generalized problem types where the numbers used in the underlying production rule model the AI engine uses are parameterized rather than instantiated. For example, a typical ACT-R system might model a simple solution path for adding $(2 + 3i) + (3 + 4i)$ as

Step 1: $(2 + 3i) + (3 + 4i)$

Step 2: $(2 + 3) + (3i + 4i)$

Step 3: $5 + 7i$.

This would require a separate model for every possible problem that the system would deliver to a student. By parameterizing each variable, we create a system that requires only one knowledge

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model per problem type plus the particular variable values for each problem. Therefore, our solution path for the same problem looks like

Step 1: (a + bi) + (c + di)

Step 2: (a + c) + (bi + di)

Step 3: evl(a+c) + evl(b+d)i. (evl means to evaluate the sum of a+c)

Problem 1: a=2, b=3, c=3, d=4, and so on for each problem to be used.

This method means that the system can generate unlimited problems to present to the students and the AI technology can respond to them since its representation of the problem is generic rather than hardcoded. For each possible step, there are multiple pathways that are permissible and we supplemented the algorithm with mathematical expression evaluators that recognize equivalent inputs (e.g., a+bi and bi+a are mathematically equivalent).

For each step in the process, the possible errors a student could make are enumerated. For each error, there is associated text that describes the error and the way to correct it. Similarly, three hints, each progressively more specific, are also created for each step in the process. The benefit of our parameterized approach to representing the problems is that these hints and feedback can also be written generically and then populated with specifics from the problem. For example, in a standard algebra problem type of ax+b=c, if a person subtracts the value of b from one side of the equation and not the other, we can write the corrective feedback as "You subtracted b from one side of the equation and not the other. You need to subtract b from both sides of the equation." However, rather than saying "b", the system would replace that b with the actual number used in the problem. This format allows for one general piece of feedback to be used in any problem of this type where the user makes this particular mistake. It is this feature that allows the student to enter his or her own problem since the system in not tied to any particular set of numbers.

METHODS

Participants

Participants were 20 students who were recruited from middle school and high schools in Fairfax and Loudoun counties in Virginia and Montgomery County in Maryland. Each one was enrolled in a geometry math class, which means that they had previously taken Algebra I, but had not taken Algebra II. It was necessary that each student had previously taken Algebra I since knowledge of how to multiply two binomials is necessary to learn the subject matter taught in the present study. However, it was also necessary that each student had not yet taken Algebra II

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since the subject matter of the present study, division of complex numbers, is a topic that is covered in the Algebra II curriculum. We wanted to make sure that participants in the present study had no prior knowledge of this topic. All participants met this criterion.

Topic Taught and E-textbook Technology Used

The topic used in the present study was division of complex numbers of the form a + bi, where i is the square root of -1. This topic is typically part of the Algebra II curriculum.

There were two core technologies used. First, for the control condition, there was the Pearson Algebra II Common Core electronic textbook used by students in Fairfax County schools. For division of complex numbers, there is a unit explaining how to divide complex numbers, followed by six practice problems. Additionally, both conditions had a 20-question paper and pencil post-test that was common to both conditions.

The experimental condition technology consisted of the AI and voice technology software described above. The instructional part consisted of both text and video versions of how to divide complex numbers.

Procedure

The participants were first screened to make sure that they did not already know how to divide complex numbers. Upon completion of the initial screening, participants were assigned to one of the two technology conditions. A total of 10 participants were assigned to each condition.

The first part of the instructional process was having participants in each group learn the concept. In the control condition, participants read the appropriate section of the Pearson e-textbook on dividing complex number problems. They then did the six practice problems listed in the e-textbook and given feedback as to whether or not they got the correct answer. In the experimental condition, participants used the present AI and voice-powered e-textbook technology. Their session consisted of learning the material, going through the assessment, and doing the six practice problems on the electronic worksheet. Afterwards, all participants were given the 20-question post-test.

RESULTS

The answers to the 20 questions on the post-test were scored based on whether the correct answer was given. The mean number of correct answers by participants, broken out by condition, is shown in Table 1. As can be seen in Table 1, participants in the Pearson electronic textbook condition averaged 4.4 correct answers or 22% on the post-test. In US schools, this is

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generally considered to be a failing grade (F). Participants using the AI and voice-powered technology averaged 17.5 correct answers or 87.5% on the post-test. In US schools, this is generally considered to be in the B+ grade range.

Table 1: Mean Number of Questions Answered Correctly Based on E-textbook Used

	Mean Number of Correctly-Answered Questions
Pearson	4.4
AI-voice e-textbook	17.5

A t-test was performed on the data and revealed a statistically significant difference between the means $t = 6.40$, $p < .00001$. This suggests that adding AI and voice/natural language technologies to e-textbooks can greatly improve performance. There is a secondary finding that is worth noting. In any educational setting, there will always be some students who learn no matter how they are taught and some who will struggle. Therefore, in addition to looking at overall means, it is useful to explore how robust an educational technology is in teaching all of the students who use it. To do this, we examined the variability in scores between the two groups to see the degree to which the technology appears to help all students who use it.

In the Pearson group, the post-test scores ranged from 0 to 16 (0% to 80% correct), suggesting that the technology is much more effective for some students than others and that it is not particularly robust across students. Only two students scored above 50%, which means eight of 10 students would receive failing grades. In the AI and voice-powered e-textbook group, the post-test scores ranged from 14 to 20 (70% to 100%). This suggested that, while some students did outperform others, in general, all students performed reasonably well. In order to test statistically whether the AI and voice-powered e-textbook is more robust across students than the Pearson e-textbook, we looked at the variability in performance. To do this, we conducted a Levene's Test for Homogeneity of Scores Variance across the two groups. The results was statistically significant, $F(1, 18) = 11.43$, $p = .003$, indicating that the AI and voice-powered e-textbook showed more consistent performance across students than did the Pearson.

Adding Artificial Intelligence and Voice/Natural Language Technologies to Electronic Books.

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The same technologies that enhanced the educational effectiveness of e-textbooks can be applied to electronic books in order to boost reading comprehension and increase reader engagement. First, the ability to query a learning platform can be useful for e-reading, especially for young readers. Querying the platform would allow readers to ask questions about the text they are reading to help increase comprehension. Additionally, readers could query the characters to learn more about them or understand decisions they make. This may be especially useful to young readers who often read stories with embedded life lessons. Such queries may help young readers to understand why the characters make the decisions they do and what the consequences of those decisions might be.

Second, the assessment feature is useful in the e-reading context as well. The value here is the same as when assessments are given at the end of units in the e-textbook. Here, the voice/natural language interface may be even more relevant. In the present project, our e-book technology was instantiated with reading material for early readers. These are precisely the children for whom it is most important to determine if they understand what they are reading. Normally, standardized assessments, such as the state assessments given to students in our home state of Virginia, USA, use multiple choice questions to assess reading comprehension. The potential drawback with this approach is that it is unclear whether the cause of an incorrect answer is a failure to understand the reading material or a failure to understand the question or the answer choices, particularly if the answer choices are not phrased a way the child would answer the question. For this reason, the dialog-based assessment may be particularly well suited for young children. This format allows children to answer questions in a way that is most natural for them.

The querying the text and assessment capabilities were implemented in an online e-book. The story chosen was “Little Red Riding Hood” as this is a simple story targeting early readers. The story is rich in content as there is a full storyline as well as a lesson to be learned. Therefore, using “Little Red Riding Hood” as the story allows children to ask factual questions about the story as well as lesson-based questions such as “Why didn’t Little Red Riding Hood listen to her mother?” or “Is it always bad to talk to strangers?” Similarly, the richness of the storyline allows the assessment module to assess understanding of both factual content and the intended lessons to be learned.

The e-book for “Little Red Riding Hood” is web-delivered. The child clicks through a series of pages. Each page consists of text and relevant picture. An audio clip reads the text on the page to the child. At any point, the child can click on an icon of one of the characters and then ask the character a question. The character then replies verbally. When the child is done reading the entire story, the assessment portion begins. Here, the child is asked a series of comprehension questions that include both factual details from the story and questions relating to lessons the

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story teaches. The child replies verbally. If the child gives an ambiguous answer, the software follows the matching protocol described earlier in the section on e-books. If the software cannot match the child's answer to a correct answer, the software explains the correct answer to the child.

DISCUSSION

The primary purpose of the research was to demonstrate the power of adding AI and voice/natural language technologies to e-textbooks and e-books and to investigate whether this would enhance learning compared to the current, primarily text-based format used in commercially-available e-textbooks. Since Pearson is one of the largest textbook publishers and a leader in e-textbooks, its e-textbook served as an ideal comparison to the present technology, which uses both AI and voice/natural language technologies to bolster learning. The results showed both a main effect for technology with regard to learning and a difference in variability in student performance.

The main effect is important because it shows that AI and voice/natural language technologies have enormous potential to improve learning when embedded in e-textbooks. Overall, students using the AI and voice-powered e-textbook performed four times better than those using the standard text-based e-textbook. This is equivalent to getting a B+ versus an F in school. This difference is not only statistically significant, but also clinically significant as it creates a low-cost, scalable means to improve education.

Equally relevant, the AI and voice-powered e-textbook technology showed itself to be robust across students, with no student scoring below 70% on the post-test and five of ten students scoring in the A range without any teacher intervention. This suggests that the technology may be highly useful in outside-the-classroom settings such as self-directed learning or home schooling. In contrast, the Pearson e-textbook did not show itself to be robust across students as scores ranged from 0% to 80% with eight of ten students scoring in the F range and only one scoring above a D. Results showed that the AI and voice-powered e-textbook technology produced consistently high scores, whereas the Pearson e-textbook produced inconsistent results that were predominantly on the low side. These results suggest that the Pearson text-based e-textbook is neither particularly effective at producing high performance nor robust across students while the present one with AI and voice/natural language technology is effective at producing high performance and is highly robust across students.

CONCLUSION

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As noted in the Introduction, there is a significant push to move traditional paper-based textbooks and books to electronic formats. While this creates ease of delivery, there has been little attempt to use current, state-of-the-art technologies such as AI and voice/natural language processing to enhance the teaching effectiveness of e-textbooks and e-books. The present paper demonstrates how the addition of these technologies can greatly improve how well students learn. Furthermore, the features outlined in this paper seem intuitively compelling. It makes sense that if a person can ask a smart phone a question and receive an answer, that a student should be able to do the same with an e-textbook or e-book. It makes sense that e-textbooks and e-books should verify that students are actually learning the material presented and, if not, provide corrective instruction. It makes sense that e-textbooks should allow students to enter their work step-by-step and receive hints when they are stuck or corrective feedback when they make mistakes. It makes sense that students should be allowed to enter their own problems into the e-textbook and get the same types of hints and feedback when solving problems, thus giving the e-textbook the opportunity not only to support the publishers' problem sets but also to support homework problem sets and test study guides supplied by teachers.

In addition to these education-enhancing feature, the present project team is working on other features that should further enhance the e-textbook effectiveness and provide further support to the education community. We note that unlike a tradition paper-based textbook or book or current commercially-available e-textbook or e-book, the present AI and voice-powered textbook technology is highly interactive and collects voluminous data regarding students' learning. These data can be used to enhance the educational process in several ways.

First, it has been long established that different students learn differently, i.e., have different learning styles. The present technology is well-suited to provide students with different content format based on diagnosed learning styles. This can be accomplished by creating different versions of the content to support different learning styles (e.g., visual, hands-on) and then using machine learning to optimize the selection of content for each user based on the user's queries, responses to the e-textbook's assessment queries, and performance on problem solving (including seeking hints).

Second, just as there are multiple ways to ask a question, there are multiple ways to answer them. A good teacher or tutor often tries to understand how a student thinks, so he or she can find the best way to explain concepts or answer questions. For example, one way to answer a question is to provide a straightforward answer. Another is to relate the question the student has asked to another concept the teacher knows the student knows about. A third might be to answer the question in terms of a real-world example or a familiar analogy. Again, machine learning could be used to optimize how the e-textbook answers student queries and presents its own assessment

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questions and corrective feedback to insure that students understand what is being communicated.

To accomplish this goal, there are two requirements. It is necessary to have multiple ways of answering questions and providing feedback that are tied to different response methods. The key is to collect the right data that can be used to inform the machine learning algorithm as to what the right method is for each student. An obvious source of data is to look at the student's overall performance, which includes responses to future assessment queries and problems that are given. However, the interaction process with the student may provide additional data that are useful. For example, if a student does not understand the response given, he or she may reply "I don't understand what you said" or something similar such as "huh?". The student may respond "I understand", but that may not be as diagnostic as one would hope because the student may either think he or she understands but does not or may be reluctant to admit to not understanding the answer. Another source of data could be follow-on questions or comments that indicate understanding our lack thereof. For example, if a student asked how to rationalize the denominator of a complex fraction and then, after receiving an answer asked, "What do I do with the imaginary part after I FOIL the denominator and combine the like terms?", the implication would be that he or she did not understand the explanation of how to rationalize the denominator. Perhaps the most useful indication that the student was given an optimal response to a query is when the student makes an insightful comment showing that he or she was able to extrapolate an answer to other contexts. For example, if a student is told to multiply numerator and denominator of a complex fraction by the conjugate of the denominator so as to rationalize the denominator (thus explaining the principle behind the process) and then he or she asks "So is this why we also multiply the denominator of a fraction by its conjugate when that denominator contains a square root?", the implication is that the explanation of the principle helped the student make a connection to another concept and is a useful way to explain concepts to him or her.

The third enhancement is data analytics. Currently, the AI and voice-powered e-textbook technology is collecting a lot of data regarding each student. These include questions they ask about the content they are learning (which may be an indication of what they understand or do not understand), responses to assessment queries, and the steps they enter on the electronic worksheet as well as the hints they request and mistakes they make during problem solving. These data provide a snapshot of how well students have learned the material and what gaps in knowledge they still have. Such data are valuable to relevant stakeholders. Parents are always interested in how well their kids are doing in school and where they need help. These data could be used to create customized reports for parents for each of their children.

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Teachers would benefit as well. Most teachers do not have the time to assess each student individually and often may not know where a class is struggling until after viewing the results of tests and quizzes. By that time, it may be hard to go back and remediate these deficiencies as they have to go on to the next lesson. This may explain why, in the United States, roughly 75% of 12th graders perform below grade level in math (National Assessment of Educational Progress, 2016). Using the current e-textbook technology, the software could prepare reports for teachers each night as students do their homework, thus providing feedback on student needs that could be used to plan the next day's lesson. Moreover, since the present technology is capable of guiding students through the learning process, this would free up teachers to spend more time with students who need extra help.

Schools and educational agencies could benefit from these reports as well. Concepts that students across the board need help with could inform educators as to what parts of the curriculum need to be strengthened. Reporting could also indicate whether some teachers need additional training, as in cases where their students perform lower than those in other classes within the same school or school district. Educational agencies are also often concerned with educational differences across students of different gender and ethnicity. The reporting provided by the present technology could provide real time insight into such differences and whether interventions (such as content customized to learning styles) are being effective.

Finally, such reporting would be valuable to publishing companies. Paper-based textbooks and e-textbooks that present content but do not collect data on student performance have no way of informing the publishing companies as to how well their textbooks are teaching students. The data from the present study suggest that current textbooks are not very effective by themselves at teaching concepts to students. As such, this places the burden on the teachers to make up the difference and get students to a proficient level. As shown above, this is an uphill battle as the majority of US students perform below grade level in each core subject. There is enormous room for improvement. The present technology could inform publishers as to what parts of their textbooks are effective in teaching students and what parts need to be improved. This would not only improve the educational system but also provide publishers who adopted such technology a decisive advantage over their competitors.

E-books can be enhanced as well in order to increase reader engagement. For example, many stories, such as "Little Red Riding Hood", that was used in the present project are written to teach young children lessons. A common pattern in such stories is to have a child be given a warning. The child then disregards the warning and the remainder of the story shows the child the consequences of the decision to disregard the warning. The reader is left to infer from the implied causal chain in the story what might happen to him or her if he or she acted the same way in real life.

One way to engage the reader and perhaps strengthen the message is to allow the reader to have input into the story by making him or her the one to make the decisions at critical junctures. This could be implemented using our voice/natural language capability whereby the character asks the reader, “What do you think I should do now?” When the reader replies, the storyline would follow a path based on the reader’s decision in order to teach the reader the consequences of that decision.

This capability could be implemented in a number of ways. The simplest is to create branching story lines at the time the story is written and fixed decision points that trigger the story lines. A more sophisticated method would be to evolve the story in real time. This would create more power and flexibility in terms of what reader could be allowed to do. Gaming technology would undoubtedly play a useful role here, coupled with AI to insure that the generated storylines still make the same teaching points.

A second type of enhancement to ebooks would allow readers to become active characters themselves in the story, thereby engaging them even further. This would be especially helpful in educational ebooks where interactions with the characters would serve pedagogical purposes as well as increase enjoyment of the story. A variant of this idea was implemented by John Leddo and his team in an interactive, educational television format (Leddo et al., 2016).

Here, an animated detective show was created in which a group of kid detectives needed to use mathematics to solve a kidnapping case. The viewer of the show was included as one of the detectives in the group. The interactivity was facilitated by the fact that the show was delivered via the Internet and the interactivity between characters was mediated using AI. Since the goal of the show was educational, the interactions focused largely on having the characters teach the viewer the math concepts (including allowing the viewer to ask for additional examples or ways to have the material taught, reflecting the learning style enhancements discussed above) and allowing the viewer actually solve the math problem needed to crack the case while supporting the viewer through hints and feedback as the viewer went through the problem solving.

The resulting interactive, AI TV technology was presented at a New Jersey, USA school district and compared to a traditional version in which the viewer simply watched the characters explain the math concepts and solve the problems themselves. Afterwards, on a post-test, student using the interactive, AI-powered version of the show scored four times higher than those using the traditional version, a result consistent with that found in the present study.

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Overall, the present technology shows tremendous promise in improving educational outcomes. This is true in terms of both the features currently implemented and potential enhancement features such as the three just described. We believe the potential is virtually unlimited in being able to provide each child with a high-quality education that is responsive to the requirements of his or her educational system and customized to his or her unique learning style and needs. As technology progresses through the 21st century, there is no reason for textbooks and other books to be stuck in the 19th.

REFERENCES

Anderson, J.R. (1982). Acquisition of cognitive skill. Psychological Review, 89, 369-405.

Anderson, J. R. (1990). The adaptive character of thought. Hillsdale, NJ: Erlbaum.

Aleven, V., McLaren, B.M., Sewall, J., and Koedinger, K.R. (2006). The Cognitive Tutor Authoring Tools (CTAT): Preliminary Evaluation of Efficiency Gains. Human-Computer Interaction Institute. Pittsburgh, PA: Carnegie Mellon University.

de Kleer, J. and Brown, J.S. (1981). Mental models of physical mechanisms and their acquisition. In J.R. Anderson (Ed.), Cognitive skills and their acquisition. Hillsdale, NJ: Erlbaum.

Gunawan, F.E. (2018). A learning recommendation to improve electronic textbook learning experience. ICIC Express Letters, 13(1), 1-10.

Ivanova, E.O. & Osmolovskaya, I.M. (2016). Electronic textbooks: didactic aspect. SHS Web Conferences, 29, 1-5.

Laketa, S. & Drakulic, D. (2015). Quality of Lessons in Traditional and Electronic Textbooks. Interdisciplinary Description of Complex Systems 13(1), 117-127

Leddo, J. (1994). Did they learn anything?: Finding out with a knowledge assessment tool. Presented at the National School Board Association Technology and Learning Conference. October, 1994.

Leddo, J. & Sak, S. Knowledge Assessment: Diagnosing what students really know. Presented at Society for Technology and Teacher Education. March, 1994.

ISSN: 2455-8834

Volume: 05, Issue: 01 "January 2020"

Leddo, J. Bisht, D., Narla, E., Saranu, R. & Titov, M. (2016). Using artificial intelligence to enhance the effectiveness of multimedia-based instruction. International Journal of Advanced Education and Research, 1(12), 30-36.

Lokar, M., Horvat, B., Luksic, P. & Omerza, D. (2011). Baselines for the preparation of electronic textbooks. Organizacija, 44(3), 76-84.

National Assessment of Educational Progress. (2016). Princeton, NJ: Educational Testing Service.

Quillian, M.R. (1966). Semantic memory. Camridge, MA: Bolt, Beranek and Newman.

Schank, R.C. and Abelson, R.P. (1977). Scripts, Plans, Goals, and Understanding. Hillsdale, NJ: Erlbaum.

