ASKING QUESTIONS TO ENGAGE WITH BIOLOGY: INVESTIGATING STUDENTS' INTERACTION AND LEARNING WITH AN AI-BASED TEXTBOOK

An emerging aspect of the digital education revolution is exploring the pedagogical opportunities and limitations of applying artificial intelligence (AI) techniques to support science learning. This study investigates students' interaction, learning and experiences with a digital tablet AI-book, which integrates the possibility to input questions and receive suggested questions, and a traditional E-book. The content of both digital versions is based on an international paper-based biology textbook. The study was conducted as part of an introductory Biology course at a Swedish university with 17 students. Students participated in two consecutive two-day learning sessions, engaging with the respective topics of energy in cells and cell signalling. The "AI-book" group (n=7) engaged with the AI book first followed by the E-book, while the "E-book group" (n=10) interacted in the reverse order. Students responded to a pre-test and post-test for each topic, and to a cognitive load, motivation and usability questionnaire. Student interactions with the books were automatically logged. Three students were interviewed about their experiences in engaging with the books. Findings revealed a learning gain and similar pattern of feature use in both versions. The possibility to ask questions and/or receive suggested questions was used rather sparingly in the AI-book. However, a higher frequency of asking questions was associated with a higher retention and also correlated positively with viewing book images more often. Additionally, correlations showed that a higher usability perception of the books was correlated with a higher intrinsic motivation to know and higher motivation to experience stimulation. Interviews revealed that while the opportunity to pose and receive questions while engaging with the currently investigated AI-based learning environment was helpful, various ideas for future potential development of the book indicate a need for a more personalized learning and feedback experience.

Keywords: Computer Supported Learning Environments, Data Logging, Educational Technology

INTRODUCTION AND MOTIVATION

One pedagogical danger of the digital revolution is that changes in presentation medium without meaningful changes in learner activity does not necessarily equate to enhanced learning (Means et al., 2009). Furthermore, the development of digital resources for learning science is progressing at a far swifter rate than the research required to ascertain their pedagogical strengths and limitations. Recent studies indicate a potential learning benefit of incorporating artificial intelligence (AI) to support science learning with digital tools. Such approaches are promising where students are required to understand ever-growing and rich knowledge, such as in biology (e.g. Corbett et al., 2010). Here, one direction is to develop digital resources that embed biology knowledge in combination with an opportunity to receive answers generated by AI reasoning systems to inputted questions. Recent work on adaptive systems that offer the opportunity to ask and select recommended questions have been shown to also increase students' engagement with content (e.g. Zhang & VanLehn, 2017).

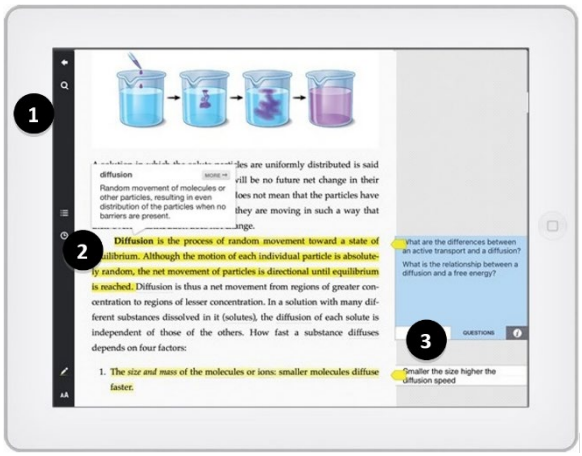

Figure 1. AI-based question integration in Intelligent LIFE showing user opportutnites to ask questions (1) and receive suggested questions from pop-up definitions (2) or based on text highlighting (3).

The resource of interest to this study is *Intelligent LIFE*, a digital textbook (Chaudhri et al., 2013) based on the international LIFE biology textbook (Sadava et al., 2011). The book integrates AI features including a 5000 concept knowledge base and algorithms to generate answers to inputted questions (Figure 1). This study concerns two versions of LIFE. An *AI-book* version offers the possibility to ask questions and (receive suggested questions)

by typing a question into a dialog box, by highlighting text, or by engaging an answer page (Figure 1). The *E-book* version lacks the question facility but both versions allow students to highlight text, link to figures and animations, and access related questions via a glossary.

OBJECTIVE AND METHODS

The aim of this study is to explore students' interaction, learning and experience with the AI-book and E-book versions of the LIFE digital biology textbook.

Study setting and participants

The study was conducted at Stockholm University, Sweden, as part of an introductory Biology course. The student participants comprised of 17 students (10 females).

Data collection and analysis

After responding to a pre-test, students were assigned to two groups. In a partial crossover research design, the "AI group" (n=7) interacted with the AI book first followed by the E-book, while the "E-book group" (n=10) interacted with the versions in reverse order. Participants engaged in two consecutive two-day (10-11 hours) learning sessions and engaged the respective topics of *energy in cells* and *cell signalling*. Various student interactions with the books were also automatically logged in real time. Each of the two learning sessions ended with students answering a post-test that measured retention (with multiple choice questions) and comprehension (with open questions requiring deeper understanding). Students also answered usability (Brooke, 1996) and cognitive load (Paas et al., 2003) questionnaires. On the final day of the study, students completed a motivation questionnaire (Vallerand et al., 1992). Three students were interviewed about their experiences three months after interacting with the books. The data corpus obtained from the questionnaires and log data was subjected to a quantitative data analysis, while the interviews were analysed qualitatively.

RESULTS

Overall, students showed a learning gain of 7.7% to 35% across both topics using both digital book versions. Mean learning gain scores are reported with effect sizes and confidence intervals in Figure 2.

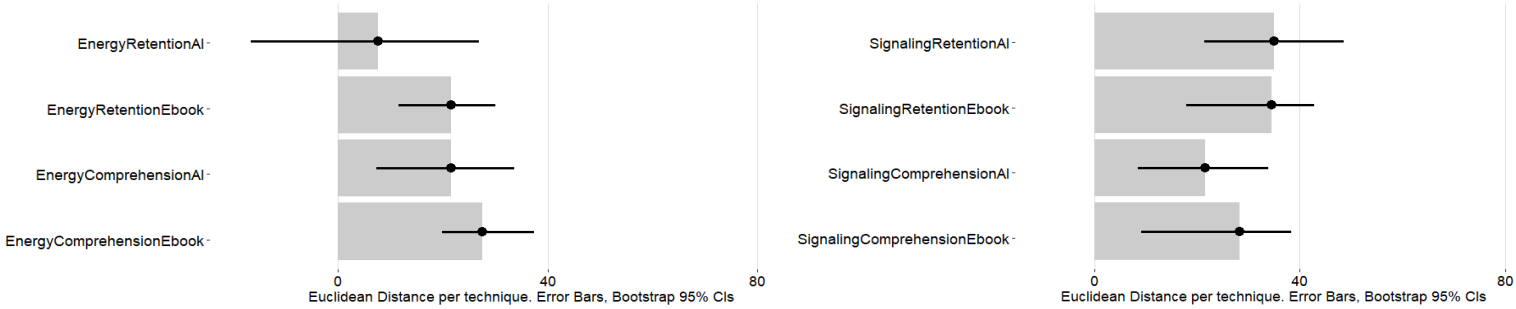

Figure 2. Learning gain (% difference between correct answers in post-test and pre-test), for each of the two engaged topics (Energy versus Signalling) and separately for the two types of knowledge measured (retention versus comprehension).

Students revealed learning gains independent of book version (Figure 2). While there is no direct evidence of a learning gain difference between the AI and E-book groups on signalling, there may be preliminary evidence of a difference in favour of the E-book on retention with the energy topic. Higher retention gains might be associated with the signalling topic, whereas comprehension gains more related to the energy topic.

There was no evidence of any differences in students' perceived cognitive load of using the two book versions, but there might be a preliminary indication of a difference between usability perception of the E-book and AI book in favour of the E-book after students learned the energy topic ($p<.1$, $\eta 2=.183$). Analysis of the log files across both versions revealed three activities of highest frequency, namely: "created highlight" (highlight text), "open page" (reading), and "open image" (viewing images). Students made little use of the AI features related to asking questions such as "asked question" and "suggested questions based on highlighting" (82 and 61 questions were posed during the experiment, respectively). We found positive correlations between retention learning gain, open image frequency and asking questions ($r=.51$ and $r=.48$ respectively). Table 1 displays correlations between usability, motivation and cognitive load.

Table 1. Correlations showing correlations between motivation, cognitive load and usability.

	Intrinsic motivation to know	Intrinsic motivation to experience stimulation	Cognitive load: Difficulty rating of using AI book	Cognitive load: Difficulty rating of using E-book	Cognitive load: Mental effort of using AI book	Cognitive load: Mental effort of using E-book
Usability (AI book)	.64**	.63**	-.85**	-.33 n.s.	.27 n.s.	.07 n.s.
Usability (E-book)	.51*	.03 n.s.	-.78**	-.70**	.24 n.s.	.05 n.s.

*Correlation significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed). n.s. = non-significant.

Qualitative analysis of the interview transcripts revealed three overall themes: "positive" themes, "negative" themes and "development" themes.

DISCUSSION AND CONCLUSIONS

While students showed learning gains and used features similarly in both book versions, the results indicate that students were more successful in learning about energy when using the E-book. The possibility to ask or receive suggested questions was used rather sparingly. Nevertheless, a higher frequency of asking questions was related to a higher retention learning gain, and correlated positively with viewing images more frequently.

Students' experiences of engaging the books showed that that a higher perception of difficulty in using both versions decreases user satisfaction. Students' usability perceptions tended to be more positive for the E-book version. Overall, a higher usability perception of the books was positively correlated with a higher intrinsic motivation to know, whereas a higher motivation to experience stimulation was positively correlated with the AI book alone. This finding implies that more cognitively open students liked both books but the students seeking intellectual stimulation perceived the AI version of the book as more usable (cf. Walker et al., 2006).

Interviews revealed that the AI-based feature of suggesting questions based on highlighting was very helpful. Students provided various ideas for potential future development of the books and suggested that integrating short quizzes providing direct feedback for reflection on one's learning would be a meaningful feature. In this study, intrinsic attitude towards learning seems to play an important role in learning effort, perhaps even more important than the technology itself. As a whole, findings indicate a potential need for a more personalized learning and feedback experience in the currently studied computer supported learning environment.

REFERENCES

Brooke, J. (1996). SUS: A "quick and dirty" usability scale. In P. Jordan, B. Thomas, & B. Weerdmeester (Eds.), Usability evaluation in industry (pp. 189–194). London, UK: Taylor & Francis.

Chaudhri, V. K., Cheng, B., Overtholtzer, A., Roschelle, J., Spaulding, A., Clark, P., & Gunning, D. (2013). Inquire Biology: A textbook that answers questions. *AI Magazine, 34*(3), 55-72.

Corbett, A., Kauffman, L., Maclaren, B., Wagner, A., & Jones, E. (2010). A Cognitive Tutor for genetics problem solving: Learning gains and student modeling. *Journal of Educational Computing Research, 42*(2), 219-239.

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2009). *Evaluation of evidence based practices in online learning: A meta-analysis and review of online learning studies.* Menlo Park CA: SRI International.

Paas, F., Tuovinen, J. E., Tabbers, H., & Van Gerven, P. W. (2003). Cognitive load measurement as a means to advance cognitive load theory. *Educational Psychologist, 38*(1), 63-71.

Sadava, D. E., Hillis, D. M., Heller, C. H. & Berenbaum, M. (2012). *Life: The Science of Biology.* W.H. Freeman.

Vallerand, R. J., Pelletier, L. G., Blais, M. R., Brière, N. M., Senécal, C., & Vallières, E. F. (1992). The Academic Motivation Scale: A measure of intrinsic, extrinsic, and amotivation in education. *Educational and Psychological Measurement, 52*(4), 1003-1017.

Walker, C. O., Greene, B. A., & Mansell, R. A. (2006). Identification with academics, intrinsic/extrinsic motivation, and self-efficacy as predictors of cognitive engagement. *Learning and individual differences, 16*(1), 1-12.

Zhang, L., & VanLehn, K. (2017). Adaptively selecting biology questions generated from a semantic network. *Interactive Learning Environments, 25*(7), 828-846.