Doing more than Teaching Students: Opportunities for CALL in the Learning Sciences

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Abstract

Computer assisted language learning systems have demonstrated ability to increase student learning in real classroom settings. In addition to the learning benefits students receive, tutoring systems can provide data to help learning sciences researchers understand how students learn. This in turn can lead to the design of more effective and efficient systems. We present two tutors developed to teach English Second Language learners the English article system and suggest opportunities in which these tutors can be used to answer key learning sciences questions.

Index Terms: CALL, ESL, article tutors

1. Introduction

Intelligent tutoring systems have shown to be effective in increasing student learning by as much as one standard deviation over traditional classroom instruction, [1] but in addition to increasing student learning, tutoring systems have the potential to contribute to the learning sciences field by providing insight into not only *what* students are learning but *how* students are learning. While most of the intelligent tutoring system work has been within well-defined domains, the development of many successful intelligent Computer Assisted Language Learning systems (See [2] for review) has positioned the learning sciences and language technology fields to investigate the process by which students learn languages and offer suggestions regarding how to design educational language technologies that lead to robust learning. This paper discusses the advantages and opportunities of using computer-based tutoring systems as a methodology for answering larger learning sciences questions illustrated with examples using two English article (*a*, *an*, *the*, *null*) tutors.

2. Tutoring Systems and the Learning Sciences

Tutoring systems facilitate the implementation of controlled, rigorous studies within a single classroom, something that is nearly impossible under the traditional model of one teacher teaching many students. For example, while lecturing to an entire class, it would be impractical to give half the students explicit instruction and the other half implicit instruction. Even if the logistics could be arranged to avoid cross-talk between groups, the instructor would need to at least double the amount of teaching time. However, using tutoring systems for in-vivo classroom studies greatly reduces instructor burden. From the student point of view, they are all doing the same task – using a computer-based tutor. But, the tasks on which students are working on can be varied in order to address specific learning sciences questions. In addition to making controlled studies easier to run in real classrooms, tutoring systems greatly increase the amount and type of information available to researchers. With paper-and-pencil assessments, often the only information obtained is the student's final answer. The process by which the student arrived at that answer is lost. Using tutoring systems, researchers (and teachers) can better understand the process by which students arrived at their final answers – How many hints did they ask for? How many times did they change their answer before making a final decision? How long did it take them to arrive at their final choice? The log data from tutoring systems give answers to these questions, offering a more complete picture of the student's learning process.

Tutoring systems serve an additional purpose for learning sciences researchers. Since classroom time is limited, instructors are often reluctant to allow researchers access to classrooms in order to do studies that are orthogonal to the educational objectives; however, well-design computer based systems that align with the educational goals of the course can help reduce this barrier by providing content-relevant instruction to the students and valuable process data to teachers and researchers.

3. Language Learning and the Learning Sciences

Not only can the introduction of tutoring systems enhance the learning sciences field but so can conducting these studies within the field of second language acquisition (SLA). For example, SLA is particularly advantageous for studying the effects of transfer on learning. Students entering the language classroom are already fluent in their native language, which can lead to both positive and negative transfer to the target language. For example, a native Spanish speaker learning the English article system will experience both types of transfer when translating the sentence *Los viernes, voy al banco* (*On Fridays, I go to the bank*.), positive transfer with respect to the noun phrase *the bank (al banco)* and negative transfer with respect to the days of the week *Fridays* (*los viernes*). Understanding how first language transfer affects student learning can help instructional designers make learning more personalized and more efficient.

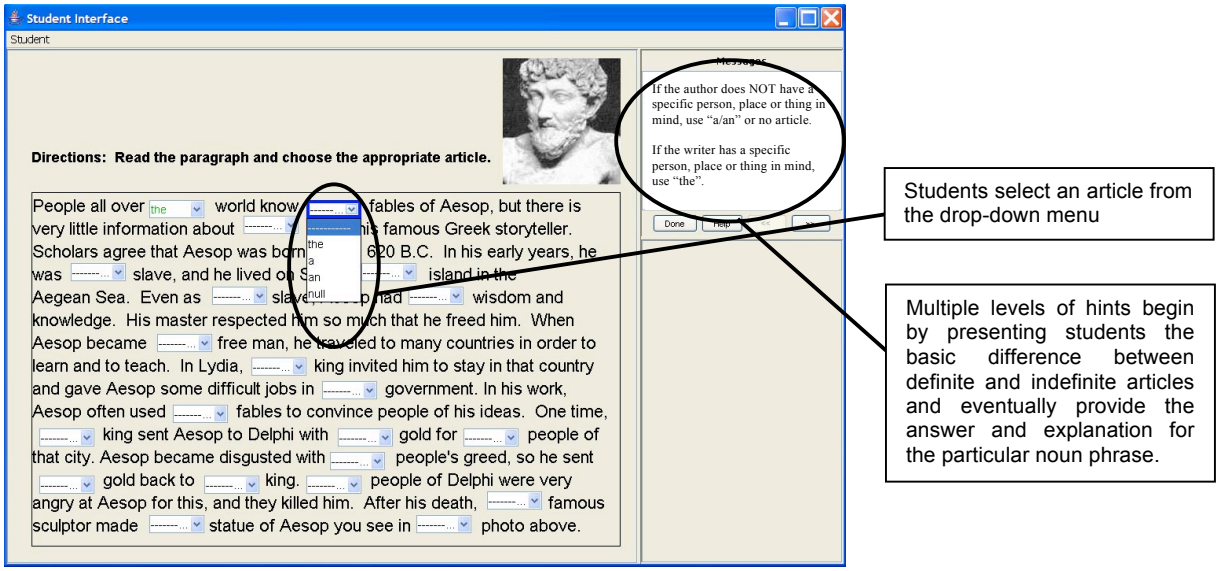

Figure 0 *Menu-based Tutor*

4. Tutor Designs

In order to begin addressing some of the above learning sciences goals, we built two tutors to teach English Language Learners (ELLs) the English article system. Both tutors were developed using the Cognitive Tutor Authoring Tools (CTAT). CTAT enables non-programmers to build example-tracing tutors through demonstration, not programming. CTAT's ease of use not only greatly expands the number of potential tutor authors but dramatically reduces the amount of time it takes to develop a tutoring system. [3, 4]

The article system was chosen as a domain to address both learning sciences and classroom considerations. Not only are articles very challenging for students to master [5] but the area is also advantageous for addressing first language transfer effects on learning. This is a particular concern for our target student population (advanced ELLs preparing to enter undergraduate and graduate programs in the United States) since although article errors rarely lead to communicative failure, even relatively small grammar mistakes can negatively affect the readers' perceptions of the writer's English and overall ability [6].

4.1. Menu-based Tutor

The menu-based tutor is similar to cloze activities found in many English as a Second Language (ESL) textbooks. Using this interface, students select an article from drop-down menus to complete the paragraph. Students do not have to identify where errors exists, only select the correct answer for each box (Figure 1).

In its current instantiation, the menu-based tutor gives students immediate feedback on each selection (the response turns green if it is correct, red if incorrect), and students have access to multiple levels of hints to help them complete the problem. The first hint presents a basic explanation of the difference between the definite and indefinite articles; the second hint asks students a guiding question with respect to the noun phrase with which they are currently working; and the third hint provides the answer and an explanation.

4.2. Controlled-Editing Tutor

The controlled-editing tutor is also implemented via CTAT through the introduction of a newly developed widget. The controlled-editing tutor allows students to insert, remove or change articles anywhere in the text. However, students can only edit articles thus preventing students from rewriting sentences in order to avoid unknown grammar constructions. In this interface, students must first identify and then correct the errors in the paragraph (Figure 2).

Similar to the menu-based tutor, the controlled-editing tutor also gives student immediate feedback after each change and provides hints. Since this interface requires students to both detect and correct errors, the first two levels of hints help students with identifying where an error occurs while the last three hints are identical to those presented in the menu-based tutor and aid in the process of selecting the correct article.

The controlled-editing task brings with it its own pedagogical challenges. Some language instructors have expressed concern over showing texts containing errors, arguing that students may implicitly learn incorrect rules. The controlled-editing tutor addresses these concerns by preventing students from moving on to the next problem paragraph until all the errors have been found and by providing students access to hints and explanations to prevent frustration and floundering.

5. Using the Article Tutors to Address Learning Sciences Questions

Introducing tutoring systems into classroom environments affords answering a variety of learning sciences questions. Following are three examples of how the Article Tutors mentioned above can shed light on significant learning sciences topics.

5.1. Task Type

Different tasks naturally lead to different skills being learned. One central thrust of the learning sciences is to understand

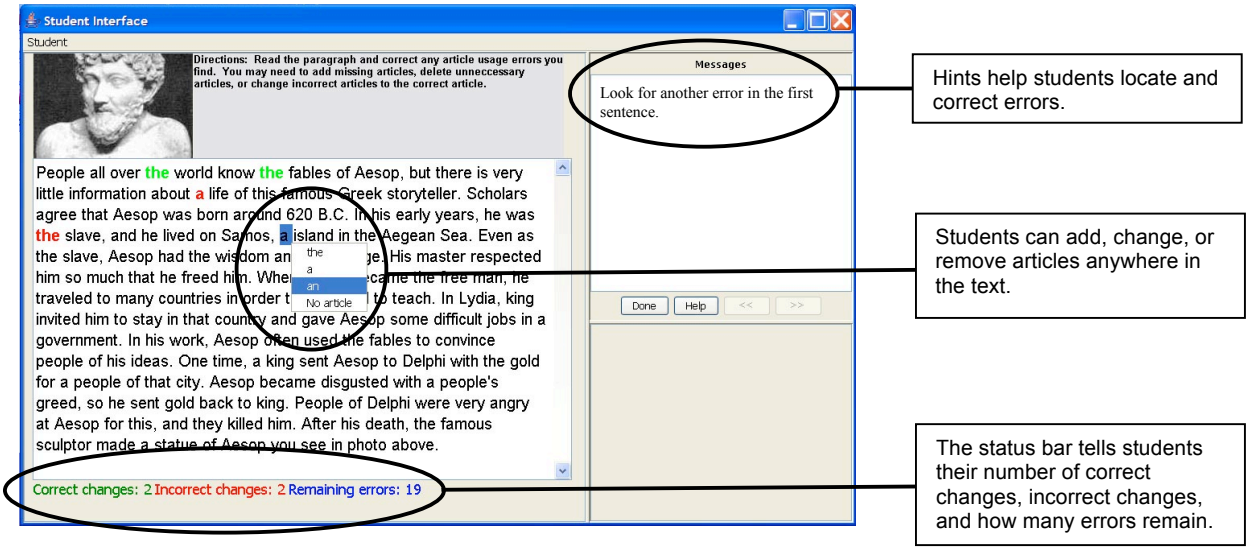

Figure 0 *Controlled-Editing Tutor*

which learning opportunities lead to robust learning. Tutoring systems can help provide an answer to this by having different groups of students complete different problems and then compare the learning gains of the respective groups. For example, while previous studies have shown that students find the controlled-editing tutor more challenging [7], it remains an open question whether the added cognitive load required to complete this task is extraneous or germane [8]. Do students make fewer errors in speech and writing after practicing article selection with the menu-based tutor or do they need practice with both error detection and selection using the controlled-editing tutor? Mainly, are the skills required for error detection a different subset than those required for production? If students detect errors by generating a response and then comparing their response to the one in the text, it rationalizes that through mastery of article selection skills, students will also increase their error detection skills. In contrast, if error detection contains additional knowledge components than those used for production, in order to increase error detection skills, students would likely need explicit practice to gain competency.

A related question is how do the skills required for these two tasks align to the educational objectives of the unit? The goal of this unit is to help students produce error-free speech and writing, not necessarily to become expert editors. Are students who have demonstrated mastery in selecting articles using the menu-based tutor able to successfully select articles when writing and speaking? Similarly, do the editing skills practiced with the controlled-editing tutor transfer to students editing their own writing?

5.2. Feedback Timing

Previous work has highlighted the trade-offs that occur with delayed and immediate feedback. While immediate feedback has been shown to reduce learning times (e.g. [9]), some argue that delayed feedback is better for long-term retention (e.g. [10]). However, little work has been done within the language learning domain. The Article Tutors can provide insight into this issue. In the current design, students receive immediate feedback after each selection or edit. The response turns green if it is correct and red if it is incorrect. However students could also receive delayed feedback; each response could turn a neutral color and feedback could be held until students complete the entire paragraph. Feedback timing is likely to affect depth of processing and thus learning outcomes. Perhaps students in the immediate feedback condition will form more shallow rules and heuristics than students in the delayed feedback condition resulting in students in the immediate feedback conditions making more errors on the robust learning measures that require deep levels of understanding. Students receiving immediate feedback may also become dependent on the tutoring system for evaluation. Mainly, students who receive feedback regarding the correctness of their edits after every change may develop a guess-and-check strategy to complete the task, a strategy that is unlikely to lead to the level of processing necessary to truly learn the material. Previous work in teaching students to write Excel formulas showed that students who had the opportunity to identify and correct errors on their own before computer intervention made larger learning gains than students who received immediate feedback [11]. It remains an open question whether this finding holds for students learning the English article system.

5.3. Personalization and Adaptability

Another interesting line of work explores the combination and sequencing of multiple tutors. According to Vygotsky's Zone of Proximal Development [12] student learning is maximized when the task students are presented with is just beyond their current competency level. Tasks that are too easy do not promote the acquisition of new skills and tasks that are too difficult are frustrating to the student. The personalization and adaptability of CALL systems addresses this challenge. As students gain mastery, they can progress to more difficult tasks. For example, students beginning to learn the article system may benefit more from the menu-based tutor that scaffolds the error detection process for students. As student ability increases, the tutor can present more challenging problems, either by presenting more challenging texts or moving to the harder problem of both detecting and correcting errors via the controlled-editing task.

6. Conclusions

Computer assisted language learning systems hold great promise to increase both student knowledge and our knowledge of the way in which students learn. Through designing systems that align with classroom goals and conducting controlled studies in real classroom environments, we can begin to understand how people learn. This

knowledge will in turn produce more effective and more efficient learning environments.

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8. References

[1] Koedinger, K. R.; Anderson, J. R.; Hadley, W. H.; and Mark, M. A. (1997). Intelligent Tutoring Goes to School in the Big City. Journal of Artificial Intelligence in Education 8(1): 30–43.

[2] Gamper, J. & Knapp, J. (2002). A review of intelligent CALL systems. Computer Assisted Language Learning, 15(4):329–342.

[3] Koedinger, K. R., Aleven, V., Heffernan. T., McLaren, B. & Hockenberry, M. (2004). Opening the Door to Non-Programmers: Authoring Intelligent Tutor Behavior by Demonstration. In the Proceedings of 7th Annual Intelligent Tutoring Systems Conference. Maceio, Brazil.

[4] Heffernan, N. T., Koedinger, K. R., & Aleven, V. A. W. M. M. (2003). Tools Towards Reducing the Costs of Designing, Building, and Testing Cognitive Models. The 2003 Conference on Behavior Representation in Modeling and Simulation, BRIMS 2003.

[5] Celce-Murcia, Marianne, and Larsen-Freeman, Diane. (1983). *The Grammar Book: An ESL/EFL Teacher's Course*. Rowley, Massachusetts: Newbury House Publishers.

[6] Master, P. (1997). The English Article System: Acquisition, Function, and Pedagogy. *System* 25, 2:215-232.

[7] Wylie, R. (to appear) Are we asking the right questions? Understanding which tasks lead to the robust learning of English grammar. Accepted as a Young Researchers Track paper at the 13th International Conference on Artificial Intelligence in Education. Marina del Rey, CA.

[8] Sweller, J., van Merrienboer , J. & Paas, F. (1998) Cognitive Architecture and Instructional Design. *Educational Psychology Review* 10(3): p251-296.

[9] Corbett, A.T. & Anderson, J.R. (2001). Locus of feedback control in computer-based tutoring: impact on learning rate, achievement and attitudes, Proceedings of the SIGCHI conference on Human factors in computing systems (pp. 245-252). Seattle, Washington, United States

[10] Schooler, L. J. & Anderson, J. R. (1990). The disruptive potential of immediate feedback. In *Proceedings of the Twelfth Annual Conference of the Cognitive Science Society*, 702-708, Cambridge, MA.

[11] Mathan, S. & Koedinger K. (2003). Recasting the Feedback Debate: Benefits of Tutoring Error Detection and Correction Skills. Proc. of the International AIED Conference 2003, July 20-24, Sydney, Australia.

[12] Vygotsky, L.S. (1978). *Mind and society: The development of higher mental processes*. Cambridge, MA: Harvard University Press.

[13] Brown, J. & Eskenazi, M. (2004.) Retrieval of authentic documents for reader-specific lexical practice. In *Proceedings of InSTIL/ICALL Symposium 2004*. Venice, Italy.