Research Report

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Project Background

Problem Statement

CTAT is an intelligent tutoring system developed by our clients, Vincent Aleven and Jonathan Sewall from CMU's Human Computer Interaction Institute. It is already a mature tool for creating cognitive tutors and supports integration with other Learning Management Systems (LMS). Cognitive tutors have been shown to be successful in improving student's learning outcomes in subjects like math. However, current adoption of these tools is still limited despite the fact that they offer flexibility and complexity when creating online tutors. Our team aims to increase the adoption of CTAT by instructors and instructional designers in higher education.

What is CTAT?

The Cognitive Tutor Authoring Tools (CTAT) is a tool suite for creating online cognitive tutors. CTAT supports customized hints and feedback through behavior graphs. The hints are written by instructors themselves and will show up when students request a hint when they work through a problem. Behavior graphs allow instructors to define different strategies that students may take when solving a problem. Instructors can define incorrect examples for the tutor, so that it will recognize those errors when students perform them. As students solve the problems, CTAT tracks their performance and provides feedback during a step, not just after.

CTAT can be integrated with LMS's such as Canvas, Blackboard, Open Learning Initiatives (OLI) and TutorShop. CTAT also supports log data related to student-tutor interactions that can be used by instructors and researchers to analyze students' learning trajectories. Figure 1 shows an example of a fraction addition tutor (left) and a behavior graph (right).

Project Background

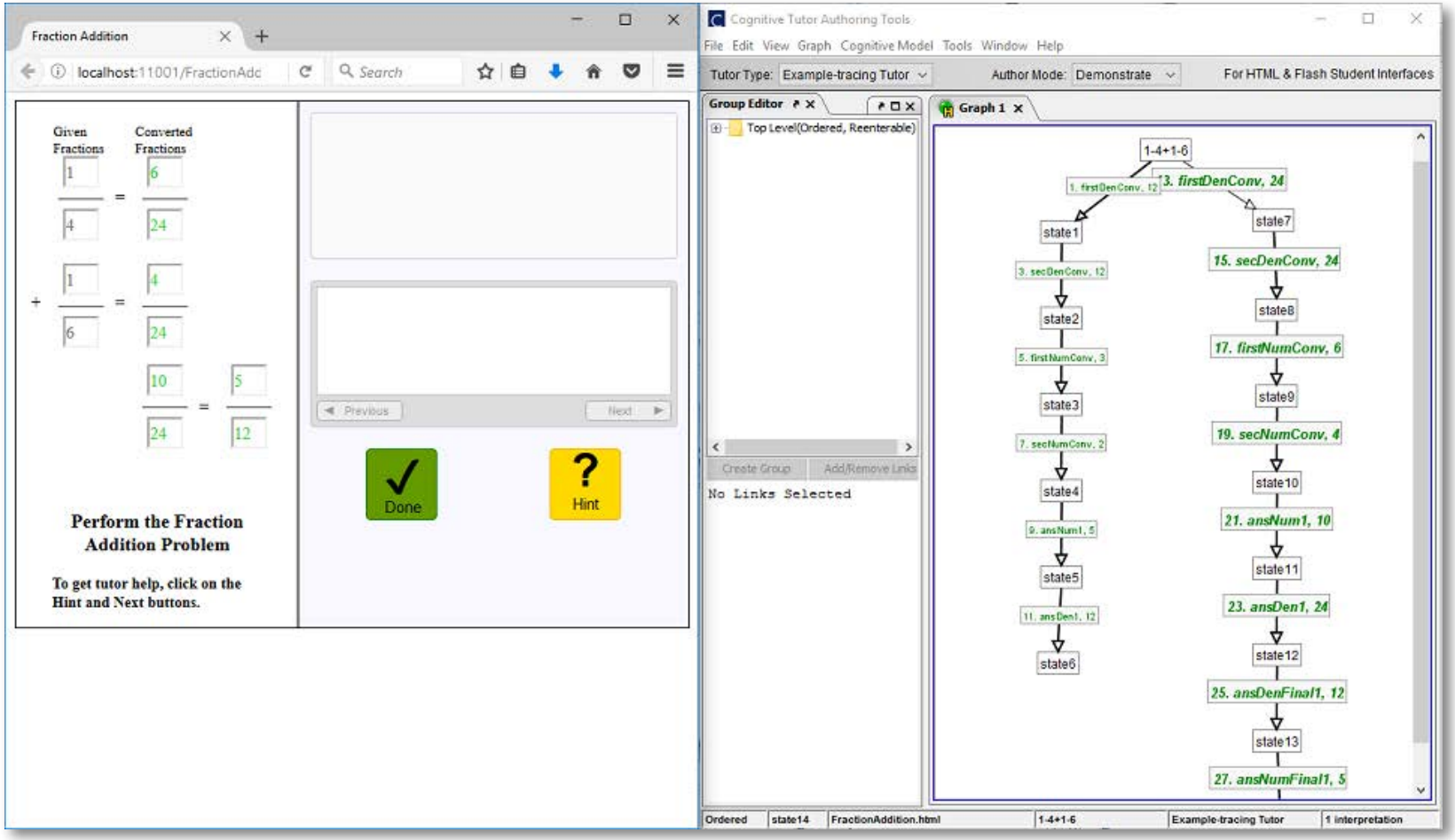


Figure 1

Methods Employed

Literature Reviews

Think Alouds with Novices

Competitive Analysis

Expert Interviews

Methods Employed

Literature Reviews

We started our research with a literature review of the history of CTAT and intelligent tutoring systems. From here, we were able to gain an understanding of the unique value that CTAT brings to the ecosystem of education technologies.

Unlike many other software, CTAT provides students with greater support and guidance in both situation of accurate and inaccurate problem solving. Some of these features include the ability to provide error feedback messages and interfaces that adapt to state of problem solving.

Additionally, CTAT is able to support dynamic solutions to a problem. CTAT tutors allow the specification of variable and interdependent steps, partial ordering and optional repetition of steps, and input substitution. Taken together, CTAT allows the creation of multiple correct solution paths for a single problem, thus managing the often diverse methods students may take to solve a single problem.

Finally, to supplement the 'inner loop' described above that captures multiple solution paths, CTAT has an 'outer loop' that makes pedagogical decisions. The outer loop tracks student knowledge growth through a learner model and selects the appropriate problems that can best help a particular student master a certain knowledge component.

Methods Employed

Competitive Analysis

We looked at 4 other currently available education technologies: ASSISTments, Schoolhouse, Qualtrics and Oppia. These target a wide range of users, from teachers and universities to businesses and the general public. With the except of Qualtrix, they tend to serve Math, Technology and other STEM fields, with a secondary focus on other domains.

All of the above products support question creation through fixed templates. Users, when designing a problem, can select from a variety of predetermined question types, such as multiple-choice, short answers, checklists and others. These templates greatly improve the ease of authoring problem sets for novice users. Conversely, the amount of customization users can apply to a each template is extremely limited. There is almost no way for question types and interactions to be designed from scratch in any of these products.

The feedback provided is limited to after question submission, if at all. ASSISTments and Oppia provide feedback to students at the end of the answer, often to let them know whether their response was right or wrong. Qualtrix, being a primarily survey software, does not tend to provide feedback, although it is possible to do so. Schoolhouse does not provide digital feedback. Problem sets designed on Schoolhouse are meant to be printed out, so feedback is provided by instructors in the traditional manner of graded worksheets.

Finally, to supplement the 'inner loop' described above that captures multiple solution paths, CTAT has an 'outer loop' that makes pedagogical decisions. The outer loop tracks student knowledge growth through a learner model and selects the appropriate problems that can best help a particular student master a certain knowledge component.

Some of these products offer unique features that supplement the user experience. Qualtrix provides real-time online collaboration, allowing

Methods Employed

multiple individuals to work on a single question set. Oppia, on the other hand, has a user community that can provide feedback for question sets and resolve technical difficulties. In terms of the interface, Schoolhouse resembles Microsoft Word, which potentially makes the program easier to intuit for novice users.

Think Alouds

We conducted 2 think alouds with CTAT novices. They were given a picture of a final tutor interface and asked to use the CTAT HTML5 editor to recreate the interface as closely as possible. One of the participants was provided with the CTAT tutorial while the other was asked to freely explore the editor. We were primarily interested in how intuitive the current interface is, and placed less significance on stylistic differences.

Participants liked the drag-and-drop feature of the HTML5 editor. Both found that adding components to the canvas was fairly straightforward. The final interfaces created also appeared very similar to the picture provided. Additionally, the participant who was given the tutorial was able to follow all of the steps without any major confusion or obstructions.

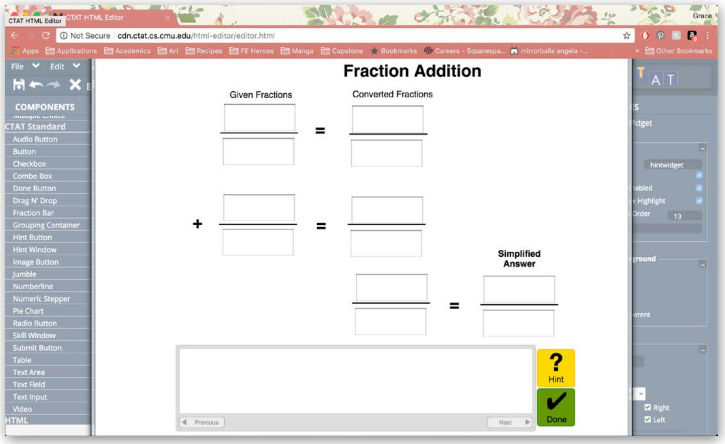
The organization of the components toolbar needed some improvement. Participants found

Methods Employed

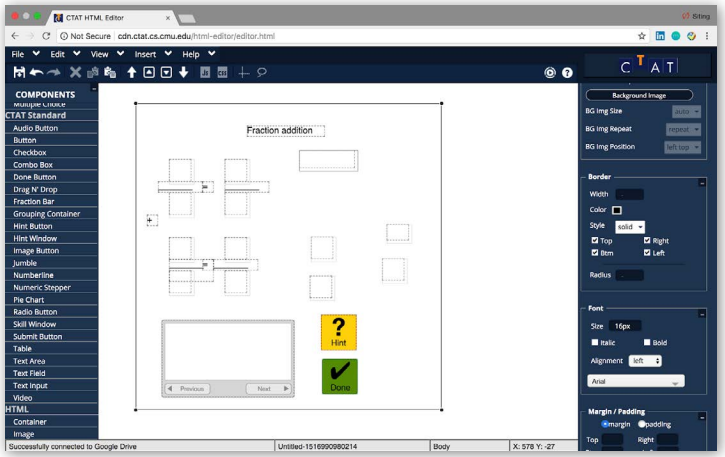
it too cluttered, with the components organized unintuitively. There were also some options that participants did not immediately understand the function of. Some examples include radio button, jumble and fraction bar.

Having more geometric primitives in the toolbar could be useful. Given that the final output is an interactive graphical interface, participants felt that there should be the options of creating diagrams more complicated than circles and lines. Currently, the creation of the fraction line felt like a 'hack' and was a struggle without the tutorial.

Finally, participants were unclear about where to seek help. There was no obvious place to get additional information about specific tasks or components from within the HTML5 editor. Additionally, when the user made an error, they expected the editor to detect and highlight the error or to provide hints and suggestions.



Above: with tutorial



Above: without tutorial. Several differences, i.e. hint widget was not used, components were not assigned ID's. So, the tutorial does help point out convenient features, as well as key steps for setting up the behavior graph later.

Key Insights

#1: Users misperceive CTAT's capabilities.

It is not immediately obvious which tasks CTAT is best suited for, and CTAT may seem more frustrating when it is not used for suitable tasks. It is powerful because of its ability to author complex problems and provide step-by-step support. However, its approach is more suitable for STEM subjects where answers are defined and precise, and less so for humanities where instruction tends to be more open ended. Additionally, CTAT may be "overkill" for simpler tasks, and users who try to apply it in those situations may see it as less useful, less intuitive or more complicated than they normally would.

CTAT's interface gives novice users the impression that it will be difficult to use. Particularly in user testing, we saw that users with no previous exposure to the software doubt the quality of its user experience based on the bare-bones look of the HTML editor. One user critiqued the text-based components bar, for example, for not even looking like a toolbar. He believed he had to use the drop down menus across the top, and complained about the inconvenience. The text-heavy tutorial also adds to the perception of difficulty. After a cursory look at the interface and tutorial, one user also assumed that the tool was code-intensive. This would be an intimidating knowledge barrier for users not already familiar with coding.

"It's not that [another tool] is better than CTAT, it's literally: what are you trying to do?"

Key Insights

#2: CTAT incurs a high cognitive load.

Instructors and students are unwilling to use a new tool that demands a higher cognitive load. For instructors, it is often much easier to use material from earlier iterations of a course when those are available. Should there be a need to create entirely new practice material, less time intensive tools are prefered over CTAT. Additionally, students and instructors who use education technologies in their courses also find it cumbersome to manage an extensive suite of tools separately.

Better integration with existing learning management systems is necessary to reduce the cognitive load of students and instructors. As Judy Brooks, director of the CMU Eberly Center describes, "...we don't want students to be focused on juggling tolls, as opposed to completing an assignment." When various tools become accessible through a single learning management system, this lowers the cognitive load of students and helps them pay more attention to class content rather than keeping track of the various tools they need to use.

Time commitment is the greatest concern for instructors when choosing a tool to use. Most instructors have multiple competing priorities of which teaching is only one of them. As such, when creating material for classes, instructors take into consideration the time they need to put in, including the time taken to learn a new tool. Professor Iliano at CMU mentioned that despite being interested creating CTAT activities for his online Computer Science course, he considers it to be a side project because it was too much of a time commitment for him right now.

Time considerations also mean that instructors want to use existing course content where possible. This preference manifests in two ways: 1) instructors tend to reuse and adapt material from previous iterations of the course instead of creating activities from scratch using new tools;

Key Insights

and 2) instructors are also more willing to put in the time to learn a new tool if the outcome serves more students. Professor Martina Rau at University of Wisconsin-Madison is a CTAT power user who has created a range of Chemistry tutors but does not use CTAT in her own classes. This, she explains, is because her classes rarely have more than 10 students, making it not worth her time to create CTAT tutors for such a small class.

"[F]aculty are busy... If they are going to put any upfront time investment, it better be worth it."

#3: There is a lack of support for novices.

Novice users are often unaware of how they can troubleshoot and resolve problems. Users inevitably run into difficulties when using a tool as sophisticated as CTAT. The lack of comprehensive online documentation and Q&A platforms creates a substantial barrier for users trying to recover from errors. Additionally, despite having a CTAT Google group with rapid response times, the forum is not well advertised and many novice users are simply not aware of it. Professor Aravind of Clarion University shared that when first learning to use CTAT, he had to drive down to CMU to sit with a CTAT developer to get his difficulties resolved. His story is indicative of how difficult it might be for other novices who may not be fortunate enough to live so close to Pittsburgh.

The current onboarding and training process is not comprehensive. Although CTAT is an extremely powerful tool, its lack of tutorials leaves

Key Insights

much of its potential undiscovered by most novice users. Lorelei Walch, an instructional designer at the CMU Eberly Center, found the online tutorials and documentation useful only for getting a basic idea. She shared that seeing someone go through the process of building a course through CTAT was most effective in getting her to understand how the separate parts of CTAT (editor, interface and behavior graph) came together.

CTAT novices feel that they need prior skills to utilize CTAT fully. In particular, our interviewees shared that an understanding of HTML, CSS, and javascript was necessary for them to create more complex interfaces and interactions. Professor Aravind, who previously had basic skills in HTML, learned javascript later to better use the tool. Professor Rau also mentioned that the more elaborate style templates she used were not supported by drag and drop interfaces, thus her PhD students had to learn coding before they could assist her with her CTAT work. In addition, she found that some of the documentation for CTAT seemed targeted at people with programming experience, making it less accessible to individuals without these skills.

Next Steps

Our next steps are to further understand specific technical barriers to adoption, including interface pain points and where breakdowns occurred. To do that, we will look into the process of creating a problem using CTAT and integrating the content with LMS platform through contextual inquiries with CTAT users. This process will allow us to identify the underlying technical barriers to adoption, such as the challenges of creating tutors for instructors and the steps that need to take to integrate the tutors with LSM. In addition, by analyzing instructors' routine tasks, we will find out the breakdowns in the journey map and explore strategies to solve these problems.

Furthermore, to help transition novice users into power users, we aim to identify the tasks for which CTAT users want technical support. This will help us to identify the parts that need more training and concrete tutorials. In order to offer better troubleshooting support, we will understand what methods current power users find to be effective for overcoming the barriers they had.

Finally, to address usability problems with CTAT, we will conduct user testing with novice users with specific tasks. For example, creating a quiz with hint messages defined at different steps, re-creating a given problem using CTAT's HTML interface, or testing an example-tracing tutor. By observing the process they take and where they have trouble, we will have a better idea of which parts of the interface are not straightforward, which is key information that we need to take into consideration when creating a redesign prototype.

Appendix

Interviewee Information

Norman Bier
Director/Principal Investigator
Open Learning Initiative

Executive Director
Simon Initiative

Judy Brooks
Director, Educational Technology & Design
Eberly Center

Lorelei Walch
Educational Technology Consultant
Eberly Center

Martina Rau
Assistant Professor, Department of Educational Psychology
University of Wisconsin–Madison

Vasudeva Rao Aravind
Associate Professor of Physics
Clarison University

Iliano Cervesato
Professor of Computer Science
Carnegie Mellon University

Appendix

Affinity Diagram