TITLE	DESCRIPTION
Case study title	MetaTutor http://www.memphis.edu/mitsc/capabilities/team-memphis-projects/metatutor/index.php
Institution name	MetaTutor is a project developed between 2006 and 2009 under NSF grant by Roger Azevedo (PI), Arthur Graesser, Vasile Rus, and Danielle McNamara (Co-PIs) at the ADL-CITSRD, Dept. of Psychology – University of Memphis. Currently, MetaTutor is a research program being conducted under NSF grant by Dr. Ronald Landis through the College of Psychology at the Illinois Institute of Technology.
Reference person	Roger Azevedo, Professor, McGill University Canada Research Chair in Metacognition and Advanced Learning Technologies Editor, Metacognition and Learning. e-mail: roger.azevedo@mcgill.ca
Background	MetaTutor was born as an interdisciplinary project involving the design, development, and evaluation of a web-based intelligent adaptive hypermedia system to (1) model key self-regulatory processes to foster students' understanding of science and (2) to provide adaptive scaffolding during learning about complex science topics. MetaTutor is intended for college and high school students, and has been tested in several ways to stress different aspects of self-regulation in the learning process (i.e. social, affective, and motivational ones). The present case study is described in detail in [1]. Students work in front of a computer system equipped with standard multimedia devices. They can draw notes, and are

TITLE	DESCRIPTION
	video and audio recorded. Finally, physiological measurements are collected (i.e. cardiac pulse, eye tracking, and facial detection of emotions).
Intended outcome(s)	The study is aimed at examining the effectiveness of SRL training in students' deployment of key SRL processes during learning. A mixed-methodology approach has been used to examine the quantitative differences in learners' SRL processes. Both theoretically-driven and empirically-based guidelines for supporting learners' SRL with MetaTutor were provided.
Technological development	MetaTutor [2] [3] is an adaptive hypermedia learning environment developed by Roger Azevedo. It has been designed to detect, model, trace, and foster students' self-regulated learning (SRL) about human body systems. Treated topics are the circulatory, digestive, and nervous systems. MetaTutor is mainly a research project. It is based on cognitive models of self-regulated learning. It aims at examining how much effective animated pedagogical agents are as external regulatory agents used to detect, trace, model, and foster students' self-regulatory processes during learning about complex topics. As a consequence, the architecture of MetaTutor is open because modules can be easily changed, defining new components or redesigning existing ones. Processing and data are decoupled in the architecture: such a solution allows easy transfer of MetaTutor from one domain to another without changes in the processing part. In general, all the domain information is external, and it's contained in separate files that can be edited easily by either domain experts or cognitive

TITLE	DESCRIPTION
	scientists.
Piloting	*Participants*. The entire sample consisted of 59 high school and non-science majors from a public high school and college in the mid-South. The analysis reported in this study represents a sub-set of this sample (N =30) since researchers only have process data (i.e., concurrent think-aloud protocols) on 15 students in each group. *Research Design*. A mixed methodology approach has been used to examine the quantitative differences between learners' deployment of SRL processes during learning. The MetaTutor experiment included a 2 (condition: SRL training, control) X 2 (time: pretest, posttest) mixed factorial design to explore the gains in participants' pretest and posttest scores on several human body systems. Participants were video and audio recorded during learning tasks to determine when they deployed certain SRL processes such as taking notes and drawing. This study focuses on the data collected in day one and four of the experiment. *Procedure*. On Day 1, participants were randomly assigned to one of two MetaTutor conditions (i.e., Control or Training). All participants completed the following: (a) a 13-item SRL quiz designed to gauge participants' existing declarative knowledge of SRL, and (b) a pretest on the circulatory system. On Days 2 & 3, participants in the Training condition spent two learning sessions (1.5 hours) learning declarative and procedural knowledge about SRL. Participants in the Control condition spent 1.5 hours learning about the digestive system and receive no SRL training. On Day 4, all participants completed a 1-hour learning session during which they

TITLE	DESCRIPTION
	provided concurrent think-aloud protocols. Equivalent forms of posttests were administered to the participants. Following the learning session, participants were given the same SRL quiz that was administered at pretest. *Product data—Learning outcomes*. The study reports preliminary results since researchers were collecting data at the time of publication. In relation to research question one, the data show that students in the Training condition scored significantly higher on the SRL quiz after training on the SRL processes and were also able to maintain their knowledge of the SRL processes. Results also indicate that there was no statistically significant difference between conditions for the matching task of the circulatory system, however, there were significant differences between groups on the labeling task and multiple choice circulatory system tests. Training condition participants outperformed those in the control condition. *Process data – Concurrent think aloud processes*. Several independent t-tests have been calculated on the means of the SRL processes used by learners in each of the two conditions. Results indicate that learners in the MetaTutor SRL Training condition deployed significantly more instances of five SRL processes. More specifically, those assigned to the Training condition engaged in more prior knowledge activation, recycled goals in the working memory (WM), monitored their emerging understanding by using (positive) judgments of learning, monitored their progress towards goals during the learning session, and used knowledge elaboration as a learning strategy.
Teaching and Learning Implications	MetaTutor is based on the assumption that students should

TITLE	DESCRIPTION
	regulate key cognitive, metacognitive, motivational, social, and affective processes in order to learn about complex and challenging science topics. Its design is based on extensive research by Azevedo and colleagues' showing that providing adaptive human scaffolding enhances students' learning about science topics with hypermedia. The research has identified the self-regulatory processes of students' learning about complex science topics. These processes include planning, metacognitive monitoring, learning strategies, and methods of handling task difficulties and demands. Training students on SRL processes with MetaTutor needs several phases. In the first phase the SRL process are modeled. After this step, the behavior of the student is analyzed to highlight what aspects are used in a good or in a poor manner. At this point, the students see video clips showing persons engaged in similar learning task. They have to stop videos whenever they see that those processes are used. Finally, students use the environment for learning. The user interface of the learning environment highlights the learning goal, and its related subgoals for the learning session. The left side of the GUI contains the list of topics and subtopics related to the goals. Both static and dynamic contents are placed in the center of the GUI. The interaction is managed by the communication dialogue box. It interacts with the student together with the pedagogical agent, devoted to assist the learner through the process of evaluating her/his understanding of the content. The interface lists the SRL processes useful in the learning session. When the student chooses a SRL process, she enhances at the same time her metacognitive awareness of the process she used during learning. Moreover, the system can track better the student's

TITLE	DESCRIPTION
	learning. On the other hand, the system can suggest a particular SRL process. In what follows the MetaTutor modules are listed: – the *Knowledge Base module* that includes the content pages and other knowledge items needed throughout the system, such as the taxonomy of the domain. – the *NLP module* and Machine Learning Component that implement functions for evaluating various student inputs (textual input, actions at the interface, time-related behavior) and send these evaluation results to other components that need them. – the *XML parser and editor* that is used to implement the authoring functionality for the designer of the system, the domain experts, and the cognitive scientists to make changes to various configurable items in the knowledge base. Moreover the parser is used for the feedback managing. – the *Production Rules module* that encodes conditions that are monitored by the ITS. Rules monitoring takes place at specified time steps that are tailored on actual data, through a polling strategy. Rules trigger if their conditions are met. A default policy is used for managing concurrent firing. – the *Log module* that records every single event by the user and the system to per- form post-experiment analyses. – the *System Manager* that controls the operations of the entire system. – the *Agent Technology module* that handles the three agents used in MetaTutor: Mary the monitoring agent, Pam the planner, and Sam the "strategizer". – the *Micro Dialogue Manager* that implements the planning that handles the multi-step, mixed initiative process of

TITLE	DESCRIPTION
	breaking the overall learning goal into more manageable sub-goals. Such a module handles the multi-turn interaction between the system and the student.
The e-learning advantage	Learning about complex and challenging science topics with advanced learning technologies requires students to regulate their learning. The deployment of key cognitive and metacognitive regulatory processes is key to enhancing learning in open-ended learning environments such as hypermedia. MetaTutor proposes the metaphor "Computers as MetaCognitive tools" to characterize the complex nature of the learning context, self-regulatory processes, task conditions, and features of advanced learning technologies.
Key points	MetaTutor is grounded in a theory of SRL that views learning as an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognitive and metacognitive processes in the service of those goals. More specifically, MetaTutor is based on several theoretical assumptions of SRL that emphasize the role of cognitive, affective, metacognitive, and motivational (CAMM) processes. Moreover, there is a fundamental assumption that learners have the potential to monitor and regulate their CAMM processes while developing a conceptual understanding of the science topic. Although all students have the potential to regulate, few students do so effectively, possibly due to inefficient or a lack of cognitive, emotional or metacognitive strategies, and knowledge. MetaTutor is both (1) a learning tool designed to teach and train students to self-regulate (e.g., by modeling and scaffolding metacognitive monitoring, facilitating the use of

TITLE	DESCRIPTION
	effective learning strategies, and setting and coordi- nating relevant learning goals), and (2) a research tool used to collect trace data on students' cognitive, metacognitive, affective, and motivational processes deployed during learning.
Conclusions and recommendations	Results indicate that SRL training is an effective method to develop students' SRL about challenging science topics with hypermedia. A key aspect of this study is to converge the think-aloud process data, with the product data to build a comprehensive model of the underlying SRL processes and an understanding of how and when the "trained" SRL processes were deployed during learning. This is a critical aspect in developing ITSs designed to foster SRL such as MetaTutor.
Additional information	**References** 1. Azevedo, R., Witherspoon, A., Graesser, A., McNamara, D., Chauncey, A., Siler, E., Cai, Z., Ruse, V., Lintean, M, MetaTutor: Analyzing Self-Regulated Learning in a Tutoring System for Biology, In: Proc. AIED (2009) 2. Azevedo, R., Witherspoon, A., Chauncey, A., Burkett, C., Fike, A.: Metatutor: A metacognitive tool for enhancing self-regulated learning (2009), http://aaai.org/ocs/index.php/FSS/FSS09/paper/view/995 3. Lintean, M.C., Witherspoon, A.M., Cai, Z., Azevedo, R.: Metatutor: An adaptive system for fostering self-regulated learning. In: AIED. p. 801 (2009)