Is Externally-Regulated Learning by a Human Tutor Effective in Facilitating Learning with Hypermedia?

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Abstract: We examined the effectiveness of self-regulated learning (SRL) and externally regulated learning (ERL) on college students' learning about a science topic with hypermedia. Eighty-two (N = 82) college students with little knowledge of the topic were randomly assigned either to the SRL or ERL condition. Learners in the SRL condition regulated their own learning, while learners in the ERL condition had access to a human tutor who facilitated their self-regulated learning. We converged product (pretest to posttest declarative knowledge and qualitative shifts in participants' mental models) with process (think-aloud) data to examine the effectiveness of SRL and ERL on learning about the circulatory system during a 40-minute session. Analysis of the declarative knowledge measures showed that the ERL condition group means were statistically significantly higher than the group means for the SRL condition on the labeling and flow diagram tasks. There were no statistically significant differences between group means on the matching task, but both groups showed statistically significant increases in performance. Further analyses showed no statistically significant differences for the distribution of mental model shift between groups. In terms of self-regulatory processes, participants in the SRL condition engaged in more frequent use of sub-goals, self-questioning, selecting new information sources, re-reading, summarizing, free searching, and enacting control over the context of their learning. In comparison, the ERL participants engaged in more frequent activation of prior knowledge, utilization of feeling of knowing and judgment of learning, monitoring their progress toward goals, drawing, hypothesizing, coordination of information sources, and expressing task difficulty.

Objectives and Purpose of the Study

Learning with a hypermedia environment requires a student to regulate his or her learning; that is, to make decisions about what to learn, how to learn it, how much time to spend on it, how to access other instructional materials, and to determine whether he or she understands the material (Azevedo, Cromley, Winters, Moos, & Greene, 2005; Azevedo & Cromley, 2004). Specifically, students need to analyze the learning situation, set meaningful learning goals, determine which strategies to use, assess whether the strategies are effective in meeting the learning goal(s), and evaluate their emerging understanding of the topic. They also need to monitor their understanding and modify their plans, goals, strategies, and effort in relation to changing contextual conditions (e.g., cognitive, motivational, and task conditions; Moos & Azevedo, 2006; Pintrich, 2000; Winne, 2001; Zimmerman, 2000). However, most students experience some difficulty regulating their learning with hypermedia, which severely affects their learning about challenging topics (Azevedo, 2005; Hmelo-Silver & Azevedo, 2006). One potential solution is to examine the effectiveness of a human tutor as an external regulating agent who facilitates students' learning with hypermedia. In this study, we examine the effectiveness of self-regulated learning (SRL) and externally-regulated learning (ERL) in facilitating both qualitative shifts in students' mental models and declarative knowledge gains (from pretest to posttest). We also examine the self- and external regulatory processes used by students and tutors during learning about a complex and challenging science topic using hypermedia.

Recent research has shown that the potential of hypermedia as a learning tool may be undermined by students' inability to regulate several aspects of their learning (Azevedo, 2005; Lajoie & Azevedo, in press; Shapiro & Neiderhauser, 2004). For example, students do not always deploy key metacognitive monitoring activities such as FOK (feeling of knowing) and JOL (judgment of learning) during learning (e.g., Azevedo & Cromley, 2004). They do not always engage in planning activities such as creating learning goals and activating prior knowledge, both of which are needed to anchor their learning of new material in previously learned material (e.g., Azevedo et al., 2004a).

When attempting to self-regulate their learning, students predominantly use ineffective strategies such as copying information from the hypermedia environment to their notes and navigating the hypermedia environment without any specific learning goals (e.g., Azevedo et al., 2004b). Also, they rarely engage in help-seeking behavior such as requesting assistance with their emerging understanding (e.g., Azevedo et al., 2005). One method for understanding students' regulation of their learning with hypermedia may be to examine how an external regulating agent such as a human tutor (external to the student's cognitive system and thus part of the learning context) may facilitate a student's self-regulated learning by prompting the student to deploy certain key SRL processes. Based on how the external regulating agent facilitates self-regulated learning, guidelines for designing adaptive hypermedia learning environments can be developed.

In this study, we investigated the effectiveness of SRL (self-regulated learning) and ERL (externally-regulated learning) conditions in facilitating college students' ability to regulate their learning about a challenging science topic (i.e., the circulatory system) with hypermedia. In this study we focused on three research questions—*1) Do different scaffolding conditions influence participants' scores on the matching, labeling, and blood flow diagram posttests, after controlling for pretest ability? 2) Are different scaffolding conditions associated with participants' ability to shift to more sophisticated mental models of the circulatory system? 3) Do learners utilize self-regulatory processes differentially between conditions?* Participants in both the *self-regulated learning (SRL)* and *externally-regulated learning (ERL)* conditions were given an overall learning goal to guide their learning about the circulatory system. However, in the (ERL) condition, participants also had access to a human tutor who provided very specific adaptive scaffolding during the course of the learning based on a tutoring script. This script prompted participants to deploy various specific self-regulatory processes at different stages of learning. The tutor used these SRL variables dynamically and adaptively during learning.

Method

Participants. Eighty-two (N = 82) undergraduate students (67 women and 15 men) from the University of Maryland, received extra credit in their educational psychology course for their participation. Their mean age was 21 years (SD = 4.8) and their mean GPA was 3.3. The students were non-biology majors, and the pretest results demonstrated that all participants had average or little knowledge of the circulatory system.

Measures. The materials consisted of a consent form, a participant questionnaire, a pretest, and a posttest, all in paper-and-pencil form. These materials were the same as those developed and used by Azevedo and colleagues (Azevedo et al., 2005). The participant questionnaire collected information concerning age, gender, current GPA, number and title of undergraduate biology courses completed, and experience with biology and the circulatory system. The pretest was comprised of four parts, all having to do with the circulatory system: (a) a sheet on which participants were asked to match 13 words with their corresponding definitions (matching task); (b) a color picture of the heart with 14 components that participants were asked to label (labeling task); (c) a sheet which contained the instruction, *"Please write down everything you can about the circulatory system. Be sure to include all the parts and their purpose, explain how they work both individually and together, and also explain how they contribute to the healthy functioning of the body"* (mental model essay); and (d) a diagram of the body with a question asking participants to describe how blood flows through the body beginning and ending with the superior and inferior vena cava (blood flow diagram). For the blood flow diagram, participants were given 8 terms to fill in the nine blank spaces, and were told one item needed to be used twice. The posttest was identical to the pretest.

Hypermedia Learning Environment (HLE). The participants used a commercially-based hypermedia learning environment to learn about the circulatory system. During the training phase, learners were shown the three most relevant articles in the environment (i.e., blood, heart, and circulatory system), which contained multiple informational sources—text, static diagrams, photographs, and a digitized animation depicting the role of the heart within the circulatory system. Together these 3 articles comprised 16,900 words, 18 sections, 107 hyperlinks, and 35 illustrations.

Procedure. The fourth author acted as the tutor in the ERL condition, while the other authors participated in individually testing subjects in the SRL condition. Informed consent was obtained from all participants, who were then randomly assigned to conditions: SRL (n = 41) and ERL (n = 41).

Commonalities Across Conditions. Participants in both conditions were individually tested. Informed consent was obtained from all participants. First, the participant questionnaire was handed out, and participants were given as much time as they wanted to complete it. Second, the pretest was handed out, and participants were given 20 minutes to complete it. Participants wrote their answers on the pretest and did not have access to any instructional materials. Third, the experimenter provided instructions for the learning task. Participants in the ERL condition had the same overall learning goal as the participants in the SRL condition.

In both conditions, an experimenter sat with the participant for the entire condition, reminding participants to verbalize if they were silent for more then three seconds (e.g., *"Say what you are thinking"*). Experimenters also reminded participants of the global learning goal (*"Make sure you learn about the different parts and their purpose, how they work both individually and together, and how they support the human body"*) as part of their instructions for learning about the circulatory system. All participants had access to the instructions (which included the learning goal) during the learning session. Participants were free to takes notes or make drawings during the learning session, although not all chose to do so. All participants were given 40 minutes to use the hypermedia environment to learn about the circulatory system. Differences between the two conditions are presented next.

SRL Condition. For the SRL condition, the instructions were: "*You are being presented with a hypermedia encyclopedia, which contains textual information, static diagrams, and a digitized video clip of the circulatory system. We are trying to learn more about how students use hypermedia environments to learn about the circulatory system. Your task is to learn all you can about the circulatory system in 40 minutes. Make sure you learn about the different parts and their purpose, how they work both individually and together, and how they support the human body. We ask you to 'think aloud' continuously while you use the hypermedia environment to learn about the circulatory system. I'll be here in case anything goes wrong with the computer or the equipment."* In this condition, the participants could only ask the experimenter for procedural assistance, such as navigation information.

ERL Condition. The instructions for the ERL condition were identical to those for the SRL condition. However, in this condition learners had access to a tutor who would help them learn about the circulatory system by providing external regulation. The human tutor was allowed to facilitate participants' self-regulated learning (SRL) by:

(1) prompting participants to activate their prior knowledge;

(2) prompting participants to plan their time and effort and monitor their progress towards goals,

(3) prompting participants to use several effective strategies to learn, such as summarizing, coordinating informational sources, hypothesizing, drawing, and using mnemonics.

We designed a tutoring script for our human tutor based upon the human tutoring literature (see Chi, 1996; Graesser et al., 1995) and recent empirical findings on SRL and hypermedia (Azevedo & Cromley, 2004; Azevedo et al., 2004a, 2004b, 2005). More specifically, the tutor used the following script to assist the learner in regulating his/her learning:

(1) Ask the participant what he/she already knows about the circulatory system, set some goals, and determine how much time to spend on each goal.

(2) Suggest participant read introduction section of the *circulatory system* article, and then:
Prompt participant to summarize; and use several strategies to learn about blood flow through the heart (e.g., coordinating informational sources); ask several questions to determine participants' understanding of the various issues related to flow; make sure participant understands the purpose of lungs; suggest watching the animation to integrate all the information; and assess whether participant has good understanding (i.e., can he/she explain the entire process in his/her own words). If the participant does not have good understanding, then have participant draw and label a diagram of the heart and assess their understanding [repeat (2)]. If they have good understanding, then proceed to the *blood vessel diagram*.

(3) Revisit global learning goal, give time reminder, state which goals have been met and which still need to be satisfied.

(4) Suggest participant read text for the *blood vessels diagram*; prompt participant to summarize content; prompt participant to use a mnemonic to remember definitions of arteries, veins and capillaries. Assess participant's understanding. If the participant did not understand, then have him/her re-read the introduction, major components, and diagrams comparing veins and arteries, and then assess understanding again [repeat (4)]. If the participant demonstrates that he/she understood, then proceed to the *blood article*.

(5) Revisit global learning goal, give time reminder, state which goals have been met and which still need to be satisfied.

(6) Activate participant's prior knowledge about blood. Prompt participant to read about the role of blood and the components of blood in the *blood* article; prompt the participant to summarize, and take notes. Assess the participants' understanding. If the participant did not understand, then have him/her re-read the role of blood and components section, and then assess understanding again [repeat (6)]. If the participant demonstrates that he/she understood, then proceed to (7).

(7) Assess progress towards global learning goal, give time reminder, and spend remaining time reviewing notes and drawings.

The tutor was instructed not to provide extensive praise, nor to provide additional content knowledge beyond that provided by hypermedia environment during the learning task.

Posttest Procedures. All participants were given 20 minutes to individually complete the posttest after using the hypermedia environment to learn about the circulatory system. Participants were not allowed to use their notes or any other instructional materials while completing the posttest. All participants completed the posttest by writing their answers on the sheets provided by the experimenter.

Coding and Scoring. The coding of the participants' answers to the matching, labeling, and blood flow tasks, mental model essays, the segmentation of the participants' verbalizations while they engaged in the learning tasks, along with the coding scheme we used to analyze the participants' regulatory behavior are described in detail in Azevedo and colleagues (2005, p. 393-397).

Participants' self-regulatory behavior. The raw data collected from this study consisted of 3,280 minutes (54.7 hours) of audio and video tape recordings from 82 participants, who gave extensive verbalizations while they learned about the circulatory system. Azevedo and colleagues' (Azevedo et al., 2005; Azevedo & Cromley, 2004) model of SRL was used to analyze the learners' regulatory behavior. Their model is based on several recent models of SRL (e.g., Pintrich, 2000; Winne, 2001; Zimmerman, 2000). This model includes key elements of Winne's (2001) and Pintrich's (2000) view of self-regulation as a four-phase process, and extends these key elements to capture a total of 35 different self-regulatory variables used by learners to regulate their learning of complex science topics with hypermedia (see Azevedo et al., 2004a, pp. 364-367; based on Chi et al., 2001). Briefly, their coding scheme consists of 35 self-regulatory processes related to *planning* (e.g., goal setting, activating prior knowledge), *monitoring activities* (e.g., feeling of knowing, judgment of learning), *learning strategies* (e.g., hypothesizing, coordinating informational sources, inferences), *handling task difficulties and demands* (e.g., help-seeking behavior), and *interest* in the task or the content domain of the task (see Azevedo & Cromley, 2004, p. 533-534). We used Azevedo and colleagues' SRL model to re-segment the data from the previous data analysis phase. This phase of the data analysis yielded 7,532 segments (M = 91.85 per participant) with corresponding SRL variables. A trained graduate student used the coding scheme to code all of the transcriptions by assigning each coded segment with one of the 35 SRL variables. Inter-rater agreement was established for the mental models was .96 (agreement on 157/164 mental model essays), and participants' and tutors' coded verbalizations was .98 (agreement on 4,242 out of 4,285 segments yielding). Inconsistencies were resolved through discussion among the co-authors.

Results

Question 1: Do different scaffolding conditions influence participants' scores on the matching, labeling, and blood flow diagram posttests, after controlling for pretest ability? To analyze changes in scores on the matching, labeling and flow tasks, we used a 2 (condition: SRL vs. ERL) X 2 (time: pretest, posttest) repeated measures mixed design. For each of these analyses, scaffolding condition was a between-groups factor and time was a within-subjects factor. Box's test of equality of covariance matrices showed that the data were robust for multivariate analyses.

Matching task. A 2 X 2 repeated measures MANOVA on the pretest and posttest data showed a significant main effect of time (Pillai's Trace = .635, F [1, 80] = 138.936, $p < .001$, $\eta^2 = .635$), but no significant main effect for condition or any significant interaction between condition and time. Learners in both conditions significantly improved their scores on the matching task from pretest to posttest. Follow up t-tests by condition showed significant differences from pre- to posttest by condition (for SRL: t [41] = -7.709, $p < .001$, $\eta^2 = .598$; for ERL: t [41] = -8.978, $p < .001$, $\eta^2 = .668$), with posttest scores being higher than pretest scores in both conditions (see Table 1).

Labeling task. A 2 X 2 repeated measures MANOVA on the pretest and posttest data showed a significant main effect of time (Pillai's Trace = .821, F [1, 80] = 366.334, $p < .001$, $\eta^2 = .821$), a significant main effect of condition (F [1, 80] = 6.047, $p < .017$, $\eta^2 = .070$) and a significant interaction between condition and time (Pillai's Trace = .094, F [1, 80] = 8.329, $p < .006$, $\eta^2 = .094$). T-tests showed no significant differences between the conditions at pretest, but there were significant differences at posttest (t [80] = -3.018, $p < .004$, $\eta^2 = .102$). In addition, follow up t-tests by condition showed significant differences from pre to posttest by condition (for SRL: t [41] = -11.715, $p < .001$, $\eta^2 = .774$; for ERL: t [41] = -15.291, $p < .001$, $\eta^2 = .854$), with posttest scores being higher than pretest scores in both conditions. The results indicate that while both the SRL and ERL conditions led to significant improvements from pre to posttest, the ERL group had a significantly higher posttest mean than the SRL group (see Table 1).

Flow Diagram. A 2 X 2 repeated measures MANOVA on the pretest and posttest data showed a significant main effect of time (Pillai's Trace = .295, F [1, 80] = 33.448, $p < .001$, $\eta^2 = .295$), a significant main effect of condition (F [1, 80] = 4.694, $p < .034$, $\eta^2 = .055$) and a significant interaction between condition and time (Pillai's Trace = .100, F [1, 80 = 8.871], $p < .005$, $\eta^2 = .100$). T-tests showed no significant differences between the conditions at pretest, but there were significant differences at posttest (t [80] = -2.731, $p < .009$, $\eta^2 =.085$). In addition, follow up t-tests by condition showed significant differences from pre- to posttest by condition (for SRL: t [41] = -2.499, $p <$

.0181, $\eta^2 = .135$; for ERL: t [41] = -5.293, $p < .001$, $\eta^2 = .412$), with posttest scores being higher than pretest scores in both conditions. The results indicate that while both the SRL and ERL conditions led to significant improvements from pre- to posttest, the ERL group had a significantly higher posttest mean than the SRL group (see Table 1).

Table 1: Means (and Standard Deviations) for the Pretest and Posttest Learning Measures by Scaffolding Conditions.

	SRL (n = 41)		ERL (n = 41)	
	Pretest *M* (SD)	Posttest *M* (SD)	Pretest *M* (SD)	Posttest *M* (SD)
Matching Task	54.59 (29.5)	82.36 (26.3)	52.72 (27.9)	84.23 (19.8)
Labeling Task	6.44 (12.4)	49.13 (23.9)	8.01 (16.9)	65.86 (26.2)
Flow Diagram	7.34 (17.6)	17.00 (28.5)	8.37 (18.3)	38.54 (41.7)

Question 2: Are different scaffolding conditions associated with participants' ability to shift to more sophisticated mental models of the circulatory system? Given that the mental model categories are qualitative in nature, we utilized non-parametric statistics to analyze mental model category changes. Specifically, we expected no statistically significant differences in the distribution of mental model categories at pretest across conditions, and this hypothesis was supported (χ^2 [2, N = 82] = .469, p = n.s.). This provides validation for the random assignment of participants to conditions, allowing for an examination of posttest scores to answer our Question 2. The results indicate that while ERL students were more likely to have a higher mental model at posttest than SRL students, the data were not statistically significant (χ^2 [2, N = 82] = 4.671, p = n.s.). These results suggest that approximately equal numbers of students in both conditions were able to reach intermediate and high levels of mental model understanding.

Question 3: Do learners utilize self-regulatory processes differentially between conditions? In this section we present the results of a series of chi-square analyses that were performed to determine whether there were significant differences in the distribution of undergraduate students' use of SRL variables across the two conditions, SRL and ERL. The details of the data transformation and statistical analyses are presented in Azevedo and colleagues (2004a, p. 356). We examined how learners regulated their learning of the circulatory system by calculating how often they used each of the variables related to the five main SRL categories of *planning, monitoring, strategy use, handling task difficulty and demands,* and *interest*. The number of learners using each SRL variable above the median proportion across conditions and the results of the significant chi-square tests are presented in Table 2. Of the 82 participants, the audio recording for 3 were not usable, thus the total N for these analyses is 79.

Planning. Chi-square analyses revealed significant differences in the number of participants who used 2 of the 4 planning variables above the median proportion across the two conditions. Overall, a significantly larger number of participants in the SRL condition planned their learning by *creating sub-goals*. By contrast, the learners in the ERL condition more often planned by *activating their prior knowledge*.

Monitoring. Chi-square analyses revealed significant differences in the number of participants who used 4 of the 7 variables related to monitoring above the median proportion across the two conditions. Participants in the SRL condition monitored their learning by *self-questioning*. However, participants in the ERL condition monitored their learning by using *feeling of knowing* (FOK), *judgment of learning* (JOL), and *monitoring their progress toward goals*.

Strategies. Chi-square analyses revealed significant differences in the number of participants who used 8 of the 16 strategies above the median proportion across the two conditions. More learners in the SRL condition learned by engaging in *selecting new information sources, re-reading, summarizing, and free searching.* By comparison, a significantly larger number of learners in the ERL condition used *drawing, hypothesizing, coordination of information sources,* and *finding a location in the environment* to learn about the circulatory system.

Task difficulty and demands. Chi-square analyses revealed significant differences in the number of learners who used 3 of the 5 SRL variables related to task difficulty and demands above the median proportion across the two conditions. More learners in the SRL condition handled task difficulties by enacting *control over the context* of their learning. In comparison, a significant number of participants in the ERL condition dealt with task difficulty and demands by *engaging in help-seeking behavior* with the tutor and *expressing task difficulty*.

Table 2: Proportion of Undergraduate Learners Using Self-Regulated Learning Variables Above the Median Proportion, by Condition.

	Condition			
SRL Variable	**SRL (n = 41)**	**ERL (n = 38)**	χ^2	*p*
Planning				
Sub-Goals	**24(59%)** [a]	13(34%)	4.687	.030
Prior Knowledge Activation	8(20%)	**32(84%)** [b]	33.026	.000
Monitoring				
Self-Questioning	**12 (29%)**[a]	2 (5%)	7.794	.005
Feeling of Knowing (FOK)	11(27%)	**29(76%)**[b]	19.322	.000
Monitoring Progress Toward Goals	10(24%)	**28(73%)** [b]	19.196	.000
Judgment of Learning (JOL)	12 (29%)	**27(71%)** [b]	13.775	.000
Strategy Use				
Selecting New Informational Source	**31(76%)** [a]	7(18%)	25.837	.000
Re-Reading	**[28(68%)**[a]	12(32%)	10.635	.001
Summarization	**[28(68%)**[a]	12(32%)	10.635	.001
Free Search	**15(37%)**[a]	3(8%)	9.227	.002
Draw	11(27%)	**29(76%)**[b]	19.322	.000
Hypothesizing	1(2%)	**16(42%)**[b]	18.374	.000
Coordinating Informational Sources	14(34%)	**26(68%)**[b]	9.269	.002
Find Location in Environment	7(17%)	**17(45%)**[b]	7.136	.008
Task Difficulty and Demands				
Control of Context	**32(78%)**[a]	7(18%)	28.052	.000
Help Seeking Behavior	4(10%)	**36(95%)**[b]	56.978	.000
Task Difficulty	8(20%)	**20(53%)**[b]	9.454	.002

Note: Degrees of freedom = 1 and n = 79 for all analyses.
Note. The **bold** type indicates the variable was used above the median frequency by more than 50% of learners.
[a] SRL group made the greatest contribution to chi-square for this variable.
[b] ERL group made the greatest contribution to chi-square for this variable.

Educational and Scientific Contributions

Our results illustrate that hypermedia can be used to enhance learners' declarative knowledge of a science topic if they are provided with a human tutor who can externally regulate their learning. We have demonstrated the effectiveness of external regulation by a human tutor in facilitating participants' learning as indicated by both performance and process data. Providing college students with a human tutor whose role is to prompt them to deploy key self-regulatory processes during macro-phases of learning and individualized micro-tutoring, both designed to foster learning of a science topic, led to significant increases in their declarative knowledge of the circulatory system. Verbal protocols provide evidence that learners who had access to the human tutor effectively deployed the key SRL processes and mechanisms that lead to significant gains in the declarative knowledge of the topic. However, while numerous participants increased their mental model through engaging in the learning task, there was no statistically significant difference between groups on this measure. These results have led to our ongoing research project examining the role of different types of scaffolding aimed at deploying key SRL processes which may be necessary to facilitate mental model shifts.

The current results show that students experience certain difficulties when regulating their own learning about a challenging science topic with hypermedia. By contrast, ERL provided by a human tutor led to statistically significant higher group mean on two declarative knowledge measures as compared to the SRL group. Based on the four SRL categories of *planning, monitoring, strategy usage,* and *task difficulties and demands*, we propose design guidelines for how specific SRL variables can be addressed to foster students' SRL with hypermedia. Within the category of *planning*, our results suggest that prior knowledge activation and planning are key SRL variables that a hypermedia environment should scaffold. To foster prior knowledge activation, the students could be asked to recall everything they can about the topic being learned, prior to beginning the learning task. Our results also indicate that several *monitoring activities* such as feeling of knowing (FOK), judgment of learning (JOL), and monitoring progress towards goals are particularly crucial to learning. To foster judgment of learning, a prompt could be inserted to have the students periodically rate their understanding on a Likert-type scale. Lastly, there are numerous effective *strategies* that could be scaffolded in a hypermedia environment, including hypothesizing, coordinating informational sources, and drawing. To close, our findings have led us to design guidelines for how self-regulated learning processes can be implemented in hypermedia environments to foster students' conceptual understanding of challenging science topics (Azevedo, 2005; Azevedo & Hadwin, 2005; Brusilovsky, 2004; Jacobson, in press).

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Acknowledgments

This research was supported by funding from the National Science Foundation (Early Career Grant REC# 0133346) awarded to the first author.