Can Students Collaboratively Use Hypermedia to Learn about Science? The Dynamics of Self- and Other-regulatory Processes in the Classroom

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Abstract: This classroom study examined the role of low-achieving students' self-regulated learning (SRL) behaviors and their teacher's scaffolding of SRL while using a Web-based water quality simulation environment to learn about ecological systems. Forty-nine 11th and 12th grade students learned about ecology and the effects of land use on water quality by collaboratively using the RiverWeb^{SM} water quality simulation (WQS) during a two-week curriculum on environmental science. The students' emerging understanding was assessed using pretest and posttest scores. Students' self-regulatory behaviors and teacher's scaffolding of SRL were assessed through an analysis of their discourse during several collaborative problem-solving episodes. Findings indicate that students learned significantly more about ecology after working collaboratively with the WQS. However, these learning gains were quite small and were related to the self-regulatory behaviors observed by the dyads and teacher's scaffolding and instruction. Analyses of video data indicate that a large amount of time was spent by the dyads and teacher in using only a few strategies, while very little time was spent on planning, monitoring, and handling task difficulties and demands. Further analysis revealed that both the dyads and teachers were using low-level strategies (e.g., following procedural tasks, evaluating the content, searching, and selecting informational sources in the WQS) to learn about the topic. Our results provide a valuable initial characterization of the complexity of self- and co-regulated learning in a complex, dynamic, technology-enhanced, student-centered science classroom. We will discuss how the results will be used to inform the design of computers as MetaCognitive tools designed to foster students' learning of conceptually challenging science topics.

Introduction

Educational researchers have successfully used student-centered methods to enhance students' understanding of science with computer-based learning environments (CBLEs) (e.g., Azevedo, Verona, & Cromley, 2001; Biswas, Schwartz, Bransford, & CTGV, 2001; Clark & Linn, 2003; Hickey, Kindfield, Horowitz, & Chirstie, 2003; Kozma, Chin, Russell, & Marx, 2000; Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004; Lajoie & Azevedo, 2000; Reiser et al., 2001; Slotta & Linn, 2000; Suthers & Hundhausen, 2003; White, Shimoda, & Frederiksen, 2000; Vye et al., 1998). These studies, however, also provide evidence that students have difficulties regulating certain aspects of their learning when they use CBLEs to learn about complex and challenging science topics such as the circulatory system, Newtonian physics, and genetics (e.g., Jacobson & Archididou, 2000). More specifically, research shows that students have difficulties regulating several aspects of their learning, including their cognitive resources (e.g., activating prior knowledge), motivation and affect (e.g., task value, self-efficacy, interest in the topic), behavior (e.g., engaging in help-seeking behavior), and the instructional context (e.g., negotiating task structure and dealing with dynamically changing structure of the instructional context).

Therefore, it is critical that we understand how students working collaboratively regulate their own learning as well as how teachers facilitate students' SRL by using different scaffolding and instructional approaches in student-centered, technology-rich science classrooms. We have therefore adopted and extended existing models of SRL (see Boekaerts, Pintrich, & Zeidner, 2000; Zimmerman & Schunk, 2001) and have used them as a lens to examine the complex interactions between students' self-regulatory behavior and teachers' scaffolding of their students' SRL when using CBLEs collaboratively in the science classroom for extended periods of time.

By adopting SRL, we make certain theoretically-based assumptions about learning (Pintrich, 2000; Zimmerman, 2001). Active learners who efficiently manage their own learning in many different ways are termed self-regulated learners (Boekaerts et al., 2000; Paris & Paris, 2001; Winne, 2001; Winne & Perry, 2000; Zimmerman, 2001; Zimmerman & Schunk, 2001). Students are self-regulating to the degree that they are cognitively, motivationally, and behaviorally active participants in their learning process (Zimmerman, 1986). These students generate the thoughts, feelings, and actions necessary to attain their learning goals. Self-regulated learning is an active, constructive process whereby learners set goals for their learning and then attempt to plan, monitor, regulate, and control their cognition, motivation, behavior, and context (Pintrich, 2000; Zimmerman, 2001). Models of SRL describe a recursive cycle of cognitive activities central to learning and knowledge construction activities (e.g., Pintrich, 2000; Schunk, 2001; Winne, 2001; Zimmerman, 2001). The empirical literature in educational psychology, classroom learning, academic achievement (e.g., Corno & Randi, 1999; Pintrich & Zusho, 2002; Newman, 2002; Perry, 2002; Zimmerman, 2001), and in the learning sciences (e.g., Azevedo, Cromley & Seibert, in press; Chi et al., 1994; Jacobson & Archidodou, 2000; Shapiro & Niederhauser, 2004) indicate that students have difficulties in regulating their learning of complex and challenging topics with computer-based learning environments (CBLEs). However, the question of whether academically low-achieving students, who have failed several science classes in high school, can regulate their learning of conceptually challenging science topics such as the effects of land use on water quality in a student-centered technology-enhanced science classroom, remains uninvestigated (e.g., Azevedo, Cromley, Winters, Xu, & Iny, 2003). Our study contributes to the vast body of literature on fostering students' learning of conceptually challenging science topics with CBLEs in student-centered classrooms (e.g., Jackson et al., 2000; White et al., 2000; Vye et al., 1998). We address the question of whether academically low-achieving students, who have failed several science classes in high school, can regulate their learning of conceptually challenging science topics such as the effects of land use on water quality in a student-centered technology-enhanced science classroom. Our study contributes to a large body of literature on fostering students' learning of conceptually challenging science topics with CBLEs in student-centered classrooms. It examines low-achieving students' SRL and the teacher's scaffolding of students' SRL in a classroom setting, and converges product data (i.e., learning gains) and process data (e.g., time and frequency of use of several SRL variables used by students working collaboratively, as well as teacher scaffolding and instructional moves). This classroom study was conducted to investigate the following research questions: (a) Can low-achieving high school students effectively use a water-quality simulation (1) (WQS) collaboratively to learn about water quality indicators and land use? (b) Do students and teacher spend the same amount of time using various regulatory behaviors to facilitate students' conceptual understanding? and (c) Do students and teacher differ in the frequency use of these self-regulatory behaviors to facilitate students' conceptual understanding?

Method

Participants

Forty-nine 11th and 12th grade high school students (22 girls and 27 boys) from a general science class volunteered to participate in this study. Ages ranged from 16 to 18 years. The students came from diverse socioeconomic and racial backgrounds. Forty-nine percent (n = 24) were African American, 41% (n = 20) were Hispanic, 6% (n = 3) were Caucasian, and 4% (n = 2) were Asian. All of these students were placed in an environmental science class after failing several required science classes in high school. The students had limited exposure to environmental science, and therefore low prior knowledge about it. In addition, we observed that students lacked general learning skills (e.g., comprehension monitoring), as well as specific science-related skills (e.g., how to round numbers). Data were collected during April and May, 2003, one month prior to the end of the school year.

Research Design

We used a one-group pretest-posttest design (49 students). Video and audio data were collected while the students worked in groups of two using the RiverWeb Water Quality Simulator (WQS) to learn about ecological systems. We collected the data on dyads of students from two of four classes taught by two environmental science teachers.

The RiverWeb^{SM} Water Quality Simulation (WQS) Environment

The WQS is a Web-based environment (http://mvhs1.mbhs.edu/riverweb/index.html) developed at Maryland Virtual High School and linked to the RiverWeb^{SM} Program originating from the National Center for Supercomputing Applications (NCSA). Targeted at the grades 8-12 science and math curriculum, the WQS depicts the effects of various land uses on water quality in an archetypal watershed. Students access WQS monitoring stations to explore how different land uses, i.e., a pristine forest, agricultural, lumbering forest, residential area, commercial/industrial area, wetlands, and urban area, affect water quality. Each water monitoring station allows students to test for physical and chemical characteristics of the tributary (termed indicators), such as total flow and nitrogen concentration. By limiting each sub-watershed to one land use, the effect of that land use on can be seen on the quality of the water that students "test" within its boundaries. The cumulative effect of the combined land use determines the water quality shown by the indicator values found at a common river outflow. After the user logs in, a map of the archetypal watershed appears. Water quality monitoring stations located throughout the watershed are depicted on the map. The user may click on the map to investigate any sub-watershed using the WQS graph window. After clicking on a station, the student is presented with a default graph that displays the variation of nitrogen over time in the top window and precipitation over time in the bottom window. However, other indicators may be selected; for example, the student could compare different indicators at the same station such as water temperature and toxins (as shown in Figure 1), could compare nitrogen concentration between two stations (e.g., residential area vs. wetlands). In addition, by reducing the range of days for each graph the student can zoom in on a particular time period and investigate daily or seasonal variations. A tour, which may be selected at login, uses frames to combine the WQS with instructions leading the user through most of the simulator's capabilities. Students can examine time series reports and scatterplots; using the time series graphs, students are able to see the impact of seasonal changes on certain indicators. Using the scatterplots, students are able to discover correlations between variables, such as the relationship between water temperature and dissolved oxygen. The goal is to foster student understanding of the complex relationships among the many land uses, indicators, and water quality in the watershed. To gain this understanding, students are first given instruction in graph interpretation. They then answer open-ended questions using the WQS which demand explanations of concepts and relationships, and finally they construct concept maps.

Data Sources and Measures

Several data sources were used to obtain an in-depth understanding of students' emerging understanding of science phenomena while using the WQS. A total of 6.12 hours of video and audio data were collected on four dyads in each of the two science classes during all on-line science inquiry sessions with WQS. This allowed for an in-depth analysis of students' behavior as well as teacher instruction and scaffolding while students engaged in collaborative science inquiry activities with the WQS. The students' emerging understanding and ability to regulate their learning was assessed through an analysis of student and student-teacher interactions during these activities. In addition to the video and audio data from student pairs, we also collected students' pretests and posttests. The paper-and-pencil materials consisted of a pretest and a posttest, which were constructed by a consulting science teacher. The pretest and posttest, which were identical, included seven complex questions which required students to: (1) demonstrate understanding of runoff with relation to different water quality indicators and sources and effects of different indicators, (2) describe and hypothesize daily and seasonal variations depicted on several line diagrams, (3) determine relationships between different indicators at different land use areas using scatter plots, and (4) construct a concept map illustrating the relationships between water quality indicators and land use. The range of total possible points for each test was 0–62. The questions were designed to give the student an opportunity to demonstrate his or her understanding of the various issues related to water quality. Question 1 was designed to determine if the students understood whether pollutants found at the mouth of a river come from runoff from land uses areas upstream (range 0 – 5). Question 2 was designed to assess whether students understood the importance of trees as a stream buffer, particularly in developed areas (range 0 – 6). Question 3 was designed to assess whether students understood how land use can cause an increase in runoff and, subsequently, more sediments and toxins in the water (range 0 – 6). Question 4 was designed to assess whether students understood that there is seasonal variation in these variables and why that might be (range 0 – 6). Question 5 was designed to assess two concepts; each scored separately, and measured whether students understood that the scale on the y-axis of any graph must be included in the interpretation of the graph, and that land usage affects nitrogen concentration (range 0 – 9). Question 6 also had two parts scored separately and was designed to assess whether students understood that the scale on the x-axis of any graph must also be included in the interpretation of the graph and that both precipitation and land use affect runoff (range 0 – 8). In question 7, students had to draw a concept map to show that they understood how various factors affect water quality (range 0 –22). Questions 1, 2, and 3 were constructed-response questions. Questions 4 and 5 combined time series graph interpretation and constructed response. Question 6 was a scatter plot graph interpretation question, and question 7 asked the students to draw and label a concept map.

Procedure

For this study, students in the environmental science course spent two weeks using the WQS. For most of the students, this was their first experience learning about water quality. On the first day of week one, the students took a pretest to assess their understanding of water-quality indicators and land use. They were then introduced to the concept of water quality and engaged in mini-labs such as testing water for nitrogen or identifying the directionality and strength of relationships between graphed water-quality indicators. During the end of week one, the students were given a tour of the WQS and taught how to use the various tools to analyze data. During week two, the students participated in three "jigsaw" activities using the WQS: In Jigsaw 1, students used a time-series graph to compare and contrast two variables, then they compared the indicators in their land use area to those in the pristine forest. In Jigsaw 2, students used the WQS to learn about two assigned indicators in each land use area. In Jigsaw 3, students used scatter plots in the WQS to analyze the relationships of all the different indicators for their specific land use area. The groups then composed concept maps showing the links between the different indicators for each area and presented their maps to the whole class. During the final class period of week two, the teachers administered the posttest to all students. Performance data, in the form of pretests and posttests, were collected for all 49 students. Process data, in the form of videotapes and audiotapes, were collected on two separate occasions over the two-week period from a sample of eight dyads from two classes. One consulting teacher acted as a complete participant during the data collection period. She is an experienced environmental science teacher who introduced the science activities to all of the students and provided scaffolding to individual student pairs during activities. The regular classroom teacher and the second author, a former science teacher, also provided scaffolding to students during their activities. The first author and several other graduate assistants acted as complete observers rather than participants in the classrooms, remaining on the sidelines to take notes, manage taping equipment, and interacting minimally with the students and teachers during class periods. Taping was done for whole class periods during which the teachers moved in and out of interaction with individual groups as they tackled the tasks in the jigsaw assignments. Therefore, data were gathered on groups of students who worked both with and without teacher assistance.

Coding and Scoring

In this section we describe the scoring of the students' answers to the pretests and posttests, the coding scheme for student and teacher SRL behaviors, and inter-rater agreement measures.

Students' Answers to Pretest and Posttest Questions

The second author and the consulting teacher constructed a rubric for scoring the students' responses to the pretest and posttest questions by initially scoring a subset (30%) of all the pretests and posttests. The rubric was refined and the two teachers scored all 98 tests individually using the revised rubric. Questions 1, 2, 3, and 7 were each given a single score; question 5 had two parts so it was given two scores; and questions 4 and 6 each had two parts so the two questions were given four scores each. This yielded 14 separate scores for each student's pretest and posttest, which were combined to calculate the each student's overall (questions 1-7 on the pretest and posttest) score out of 62 for each test.

Students' and Teachers' Regulatory Verbalizations and Behavior

The 6.12 hours (367 minutes) of audio and video tape recordings from 14 episodes provided the raw data for the analysis of students' self-regulatory behavior and teachers' scaffolding of SRL. Azevedo, Cromley, & Seibert's (in press) original model of SRL was modified and used for analyzing the students' and teachers' regulatory behaviors and adapted to fit the use the WQS in the classroom. Their model is based on several recent models of SRL (Pintrich, 2000; Winne, 2001; Winne & Hadwin, 1998; Zimmerman, 2001). It includes key elements of these models (i.e., Winne's [2001] and Pintrich's [2000] formulation of self-regulation as a four-phase process) and extends these key elements to capture the major phases of self-regulation in a complex technology-rich student-centered science classroom. The classes, descriptions and examples of the planning, monitoring, strategy use, and task difficulty and demands variables used for coding the learners' and teacher's regulatory behavior are described in the Appendix. The classes are: (a) planning and goal setting, activation of perceptions and knowledge of the task and context, and the self in relationship to the task; (b) monitoring processes that represent metacognitive awareness of different aspects of the self, task, and context; (c) efforts to control and regulate different aspects of the self, task, and context; and, (d) various kinds of reactions and reflections on the self and the task and/or context. The model also includes behavior of the teacher when she provided scaffolding of and instruction in SRL-related behaviors in order to enhance students' understanding. ***Teacher-scaffolding*** refers to any teacher–initiated move that has the intention of facilitating students' understanding through various self-regulatory behaviors. ***Teacher-instruction*** refers to any teacher–initiated move that has the intention of specifically directing students' SRL. For this study and context, this model was adapted to include verbal as well as non-verbal behaviors specific to the tasks students engaged in while learning with the WQS. As such, video data as well as audio data were used to provide evidence of teacher and student SRL behaviors.

Inter-rater Agreement

Each teacher scored each student's questions on the pretest and posttest (i.e., 7 questions with a total of 14 scores x 49 students x 2 tests = 1372 individual scores). Each teacher was instructed to independently code all 1372 scores on the pretests and posttests using a scoring rubric developed by both science teachers. Then inter-rater agreement was established for the scoring of the learners' pretest and posttest answers by comparing the individual coding of the high school teacher and the second author. There was agreement on 66 out of 66 randomly selected pretests and posttests, yielding an inter-rater agreement of 100%. For SRL behavior variables and time, inter-rater agreement was established on 289 out of 305 coded segments (27% of codes), yielding inter-rater agreement of 95%. Inconsistencies were resolved through discussion between the experimenters.

Results

Question 1

Can low-achieving high school students effectively use a water-quality simulation (WQS) collaboratively to learn about water quality indicators and land use? We examined the shift in students' learning (from pretest to posttest) by using a paired samples t-test. There was a significant difference between the students' mean pretest score and their mean posttest score [t (48) = -7.03, $p < .001$]. However, while there was a significant shift in the test scores, the students' mean score was low on both the pretest (M = 12.1%, SD = 4.5) and the posttest (M = 19.1%, SD = 6.0).

Question 2

Do students and teacher spend the same amount of time using various regulatory behaviors to facilitate students' conceptual understanding? We examined whether the relatively small (yet significant) learning gains from pretest to posttest were due to differences in the amount of time that both students and teachers spent regulating students' learning with the WQS across each of the four SRL variables (planning, monitoring, strategy use, and handling task difficulties, and demands). A MANOVA was conducted to determine whether students, teacher scaffolding, and teacher instruction differed in the amount of time spent on each of these SRL variables (see Figure 2). There was a significant difference in the mean time that learners spent regulating their own learning and the amount of time the teacher spent on externally regulating the students by using scaffolding and direct instruction (F [3, 117] = 19.32, $p < .05$). Overall, students spent significantly more time regulating the own learning than the teacher spent on regulating students' learning either by instructing or scaffolding. There were also significant differences in the amount of time students and teacher spent using different strategies to regulate students' learning. There were no differences in the amount of time spent between planning, monitoring, and handling task difficulties and demands. Multiple pairwise comparison tests found significant differences between the time spent by students and teachers on scaffolding and instruction for four SRL variables. Learners spent significantly more time using strategies to regulate their learning (F [2,39] = 10.96, $p < .05$) than the teacher did in providing direct instruction on the use of strategies, which was significantly more than the time she spent on scaffolding students' use of effective strategies (M = 294.4 sec, SD = 236.3; M = 143.0 sec, SD = 78.0; M = 39.0 sec, SD = 35.9, respectively). The teacher spent significantly more time instructing students how to plan their learning (F [2,39] = 10.26, $p < .05$) that she did scaffolding their planning or that students spent planning their own learning (M = 36.0 sec, SD = 5.5; M = 12.7 sec, SD = 5.5; M = 1.8 sec, SD = 5.5, respectively). However, learners and teachers tended to spend the same amount of time regulating their own and her students' monitoring activities (F [2,39] = 0.20, $p > .05$), and handling task difficulties and demands (F [2,39] = 3.14, $p > .05$).

Question 3

Do students and teacher differ in the frequency use of these self-regulatory behaviors to facilitate students' conceptual understanding? Third, we examined how learners and teachers regulated the students' learning of the ecology system using the WQS by calculating how often teacher instruction, teacher scaffolding, and/or student behavior reflected a variable relating to one of the four main SRL categories. We examined whether the frequency of use of each of the variables relating to the four main SRL categories of planning, monitoring, strategy use, and task difficulty were used significantly differently in teacher instruction, teacher scaffolding, and student behavior. A total of 1143 segments were coded based on 6.12 hours (367 minutes) of video from the four dyads in each of the two classes. Chi-square analyses revealed a significant difference between the frequency of these variables used between students, teacher scaffolding, and teacher instruction [χ^2 (6, 1143) = 145.16, $p < .001$] (see Table 1). Due to the overall significance, we probed further to examine what specific SRL behaviors the students engaged in and teachers instructed or scaffolded while learning with the WQS. In this section, we present a detailed account of each of the specific SRL variables used by students and teachers to regulate the students' learning of ecology with the WQS.

Planning

Chi-square analyses demonstrated that students and teachers engaged in very few behaviors associated with category of planning, accounting for only 4% of all the codes. Under planning, students and teachers were coded for behaviors related to planning (P), activating prior knowledge (PKA), stating goals (G), or recycling a goal in working memory (RG). Students displayed no behavior associated with prior-knowledge activation or stating goals. Indeed, student moves were only associated with 1% (2) of codes in this category, due to a few instances of planning (less than 1%) and a few recycling of goals in working memory (less than 1%). Teachers provided little in the way of instruction to students for planning, only 3% of total codes, and virtually no scaffolding of these SRL behaviors, less than 1% of total codes. The majority of teacher moves in this category were to instruct students on their goals (2%). Teachers did not often activate students' prior knowledge (less than 1%) and there were only a few instances of teacher instruction of student planning (1%).

Monitoring

Chi-square analyses demonstrated that students and teachers also engaged in very few behaviors associated with category of monitoring, accounting for 11% of all the codes. Under monitoring, students and teachers were coded for behaviors related to expressing a judgment of Learning (JOL), partner questioning (PQ), monitoring their progress toward goals (MPTG), teacher questioning (TQ), and expressing a feeling of knowing (FOK). Student moves associated with monitoring were responsible for 7%; but the majority of student moves in this category were partner questioning (2%) and teacher questioning (4%). There were few instances of judgments of learning (1%), feelings of knowing (less than 1%), and monitoring progress towards goals (less than 1%). Teacher instruction and scaffolding of monitoring accounted for 4%, with teachers helping students monitor their progress towards goals (2% each for TI and TS). Teachers did not scaffold or instruct students with respect to questioning, judgments of learning or feelings of knowing.

Strategies

Chi-square analyses demonstrated that students and teachers engaged in many behaviors associated with category of strategies, accounting for 78% of all the codes. Under strategies, students and teachers were coded for behaviors related to following directions (FD – *students only*), giving procedural directions (Pro - *teachers only*), content evaluation (CE), searching the environment (S), and selecting a new informational source (SNIS). Student moves associated with strategies were responsible for 63% of total codes. The majority of student moves in this category were following directions (32%). Students also engaged in selecting new information sources (18%), searching (8%), and evaluating content (6%). These observations were expected, as the jigsaw tasks required these behaviors for completion. Teacher scaffolding of strategies accounted for 4% of moves, including helping students evaluate content (2%) and understand procedures (1%). Teacher instruction of strategies accounted for 11% of moves, including using procedures which accounted for 10% of all moves, and instruction on content evaluation accounted for 1% of all moves. Teachers provided no other strategy help or instructions.

Task Difficulty and Demands

Chi-square analyses demonstrated that students and teachers engaged in very few behaviors associated with category of task difficulty and demands, accounting for only 7% of all the codes. Under task difficulty and demands, students and teachers were coded for behaviors related to time and effort planning (TEP), and help-seeking behavior (HSB). Student moves associated with monitoring was responsible for 5% of total codes. The majority of student moves in this category were help-seeking behavior (5%), usually concerning procedural questions. Students engaged in virtually no time and effort planning (less than 1%). Teacher scaffolding and instruction of task difficulty and demands (less than 1% and 2%, respectively) was spent helping students plan their time and effort.

Discussion

Our results show that low-achieving students tend to benefit little from web-based hypermedia learning environments designed to foster their learning of challenging science topics. Despite the performance data showing significant results, the process data including the time and frequency of students' SRL and teacher's scaffolding and instructional moves use disproportionate amount of time and number of SRL moves during learning. The process data provide evidence that students' poor performance on the pretest-posttest shift is due to their failure to deploy key SRL processes and mechanisms which may have led to significant shifts in conceptual understanding. In addition, the same data show that the teacher rarely deployed scaffolding and instructional moves aimed at fostering students' self-regulated learning of ecology.

With regard to the first research question, the results of this study showed that students learned more about the effects of land use during the two-week period in which they used the WQS collaboratively in the ecology class. Despite the statistically significant results on their scores from pretest to posttest, the shift in scores is rather small (7%) and there is ample room for increases in their learning of ecology since the mean for their posttest was relatively small (19%). We can conclude that while these web-based hypermedia learning environments can potentially foster students' learning, not all students have the self-regulating skills necessary to learn from these rich environments. Our results indicate that providing low-achieving students the opportunity to learn with CBLEs will lead to inferior shifts in learning. This finding is consistent with the majority of studies on non-linear, random access hypermedia environments with flexible access and a high degree of learner control (e.g., Azevedo, Cromley, & Seibert, in press; Azevedo, Guthrie, & Seibert, in press; Jacobson & Archodidou, 2000). With regard to the second and third research question, our extensive process data indicated that students and teacher differed in the amount of time and the frequency use of self-regulatory behaviors during learning with the WQS. Students tended to spend more time on and use more self-regulatory skills followed by teacher instructional moves and then teacher scaffolding. Also, students and teachers used strategies as a predominant SRL variable during learning with the WQS. The second most often used SRL variable by students and teachers was monitoring. The quantity (i.e., amount and frequency of SRL variables) and quality of the strategy and monitoring processes used by students may reveal the reason why students gained so little knowledge of ecology with the WQS. The verbal protocols provide process data to indicate that they used these SRL processes, and the chi-square analyses together with the product data show that the use of these processes led to significant increases in their understanding of the science topic. Students regulated their learning by using mostly ineffective strategies and metacognitive monitoring and did very little planning. In contrast, teacher's instructional and scaffolding moves involved using strategies to facilitate students' learning. These findings highlight the value of converging product and trace data—i.e., while the statistical analyses revealed significant differences in the time and frequency data, the explanation lies in the analysis of the quality of each of these SRL moves used by both students and teachers. For example, despite spending a significant amount of time regulating their learning and spending a disproportionate amount of time using these strategies the process data reveals that one possibility students learn little with the WQS may be because they were using low-level strategies such as following directions and searching the WQS without a specify goal. Furthermore, the relative amount of time spent by the teacher's instructing and scaffolding were relatively fewer than students' moves and the quality of those moves can also be considered low-level.

Endnotes

(1) The original designers and developers of the Riverweb WQS labeled it as a simulation-based environment, however, we consider it to be a web-based hypermedia learning environment since is provides students access to multiple representations of scientific information in multiple formats including text, and diagrams, graphics in a non-linear fashion.

(2) In percentages cited are of total moves made by students and teachers.

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