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Roger Bruning

University of Nebraska-Lincoln

Arthur I. Zygielbaum

University of Nebraska-Lincoln

Neal Grandgenett

University of Nebraska at Omaha, ngrandgenett@unomaha.edu

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Using Online Learning Resources to Promote Deeper Learning

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Roger Bruning and Arthur Zygielbaum
National Center for Information Technology in Education
University of Nebraska-Lincoln
Lincoln, Nebraska

Neal Grandgenett
Office of Internet Studies
University of Nebraska, Omaha
Omaha, Nebraska

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ABSTRACT

This paper describes research on four web-based learning applications that employ a variety of assessment approaches and student tracking and data aggregation mechanisms. These applications are aimed at promoting deeper learning in web-based learning applications and courses and at facilitating a research-based, design experiment approach to prototype development and improvement. Developmental research on two of these tools, Affinity Learning and Critical Thinking, is discussed in this paper. Affinity Learning uses database-driven software to capture the teaching skill of a master teacher. Students are guided through online activities and assessments in accord with their skills and rate of learning. When a student outcome is unanticipated in the software/database, the teacher is solicited for help. In offering that help, the teacher designs a new activity and assessment that is incorporated into the environment. The Affinity environment grows from an initial state to more and more sophisticated capabilities. The Critical Thinking Tool requires students to make and justify their answers to queries about web-based instructional content. The tool's database then graphically displays all students' choices, plus their rationales. Students are asked to review and rate the quality of others' rationales and to modify their own as needed. Both tools provide fine-grained information on student decision-making and performance that is useful for informing improvements in design. Both also have demonstrated their ability to produce student learning and promote deep understanding of concepts and principles.

INTRODUCTION

This paper describes research on four web-based learning applications that are aimed at promoting deeper student learning in web-based units and courses and at facilitating a research-based, design experiment approach to prototype development and improvement. The current studies are part of a research agenda aimed at developing experimentally validated design principles for web-based instruction. We believe that by applying key principles from the theoretical framework of cognitive science (Bransford et al., 1999; Bruning, Schraw, & Ronning, 1999; Ericsson & Kintsch, 1995), applications can be designed that enhance users' engagement in web-based materials and promote deeper understanding. In these studies we focus on two broad instructional design principles.

The first principle relates to the need to link new knowledge to students' existing knowledge structures and embed it in authentic learning contexts. Our attempt to operationalize this principle has led us to design technology-supported instruction involving students with data, concepts, and principles applicable to today's world. We also have sought to actively involve students in deep conceptual questions and to encourage flexible thinking and problem solving. We have attempted to monitor development of student understanding in these web-based technologies through systematic use of embedded assessments and student self-assessment.

The second principle relates to social constructivist views of learning, providing social support and scaffolding for web-based student learning through interactions with others. Relevant design features in our systems include assisting and coaching students by suggesting possible approaches to problems, helping them clarify their thinking, and having them test a variety of approaches to solving problems. We also are attempting to enhance interaction by connecting students with teachers, other students, and experts during learning. Our applications are designed as an additional resource to teachers and classrooms, rather than replacing these valuable assets to student understanding.

We currently are working with four web-based applications that embody these design principles. The first, called the Affinity Learning Tool, is based on relatively simple database-driven software. We have, in effect, used this tool to capture the teaching skill of a master mathematics teacher. Students are guided through online activities and assessments in accord with their skills and rate of learning. When a student outcome is unanticipated in the software/database, the teacher is solicited for help. In offering that help, the teacher designs a new activity and assessment that is incorporated into the environment. The Affinity environment grows from an initial state to more and more sophisticated capabilities.

The second, a Critical Thinking Tool, is aimed at helping students warrant their assertions and develop their reasoning ability. It requires students to make and justify choices related to web-based instructional content. The tool's database then graphically displays students' choices, plus their rationales. Students are asked to review and rate the quality of other learners' rationales and to modify their own as needed.

The third application, an Information Gathering Tool, gives students a framework for gathering information in a web-based environment. The frameworks vary, including the presence or absence of a matrix for organizing information and alternative ways to move information from the web to the tool. Research findings from studies with high school and college students show that students using the structured version of the tool gather more information and learn higher order relationships better.

The fourth application, the Virtual Teacher Coaching Tool, provides personalized cognitive and motivational coaching for students as they work in web-based materials. Responding to data gathered dynamically from the students' performance, the tool gives course instructors a virtual web presence within various sections of web-based units. Applications we are testing experimentally include using the tool to build self-efficacy, increase attributions to effort, encourage adaptive study strategies, and help students set and monitor goals.

In the remainder of this paper, we will describe research on two of the tools, Affinity Learning and Critical Thinking, to illustrate our approaches to instructional design and assessment. We outline the tools' key design features, plus briefly describe our research approach and findings. We are using assessment data from student learning and engagement to make the tools adaptable and functional for the widest range of students. We also are closely examining student reflections on their levels of understanding in light of their own and others' performance.

AFFINITY LEARNING TOOL

Human instruction is notably weak or missing in many developmental math courses, and many universities are reluctant or unable to commit scarce instructor resources to courses that are viewed as remedial. The learning environment of Affinity Learning provides the advantage of more interactive and personalized instruction than what is usually now available in developmental math courses. We feel that such students need instructional help beyond their typical resources and setting and that well-designed software can provide such help.

Approach. Mathematical modeling was targeted as the primary content area within the project, because mathematical modeling is both an important topic in today's mathematics classroom, and an unusually difficult process to teach in the traditional classroom. Mathematical modeling can be defined as a mathematical process that

involves observing a phenomenon, conjecturing relationships, applying mathematical analyses (equations, symbolic structures, etc.), obtaining mathematical results, and reinterpreting the model (Swetz & Hartzler, 1991). Our proof-of-concept project was accomplished in three phases.

In Phase 1 a specific sample module was designed that targeted the concept of mathematical acceleration. The module consists of multiple small lessons, each of which is a “fuzzy node” consisting of an activity, an assessment, and an identified number of outcomes. Outcomes might be “correct” or “erroneous”. The Affinity environment interconnects the nodes based on the outcomes. Correct outcomes lead to subsequent activities, incorrect ones to remediation. Unexpected outcomes lead to new fuzzy nodes. In other words, we seed the “knowledge garden” with what we can predict. As the tool is used, the garden is invested with new nodes and grows. As experience is gained, the network of nodes grows, leading to a more capable electronic tutor. A high school master teacher in mathematics developed the nodes and node structure for the acceleration example. The online presentation was in HTML with Java augmentation. Database operations were performed using MySQL and PHP scripting.

Phase 2 consisted of observing a sample set of students as they used the developing module. This provided a use sample for refining the software and interfaces, and also enabled us to develop a graphical representation of student progress through the module. Finally, during Phase 3, students were tested using the Affinity Learning environment and a conventional environment. At the end of this three phase effort, we have the following outcomes: 1) a demonstration module for Affinity Learning as it relates to mathematical modeling within the construct of acceleration, 2) a graphical profiling process to track student progress, and 3) descriptions of our fundamental design principles, resultant prototypes, and strategies for dealing with student learning within the Affinity Learning context.

Results. Pretest scores in the field test with high school students indicated no differences between the online and paper vs. pencil groups ($t = -.42, p < .68$). The posttest results suggested a small, but significant ($t = 1.69, p < .05$) advantage for the online students, with an average posttest gain of 10% for students using the online module and no gain for students using a paper and pencil format. The field test students reported a strong preference for the interaction that the computer provided within the module, particularly the simulations within the program, and generally confirmed that interactivity was of key importance for their learning.

One of our goals was obtaining a fine-grained analysis of student performance within the Affinity Learning tool. Figure 1 indicates the average time spent by female high school students on each node. Figure 2 indicates the same for male students. As can be seen, girls tended to spend more time in the introductory nodes and in the final testing. Boys, on the other hand spent less time in the introduction and more time in “contact the teacher.” Girls performed better on the posttest.

Illustrating another kind of data display, Figure 3 shows the nodes visited over time by a particular female student. Successful traversing of the fuzzy node network is indicated by a timeline flowing steadily down. Upward jumps indicate return to earlier nodes or to earlier remedial activities. Note that there is some fluctuation in the beginning as the student becomes familiar with the topic and the tool. The timeline demonstrates a noticeable downward shift which we’ve come to call the “Eureka moment” when the student begins to comprehend the topic. The fluctuation at the end indicates either that the final assessment of the student’s equation is intrinsically hard or that we did a poor job in aiding that testing online.

These figures give a sense of the possibilities for an intimate “look” at student learning as they tackle a complex topic. Many questions can be raised. Can we predict from early node performance how a student will perform on later nodes? If we can, then we can tailor the nodes to fit that student’s learning characteristics. Can we discriminate poor presentation and assessment methods from student performance? If we can, then we can improve the presentation and assessment virtually continuously as the tool is used.

Average Time Spent on Each Node - Females
Average amount of time all students spent on the node
Node cases: Average Time Spent

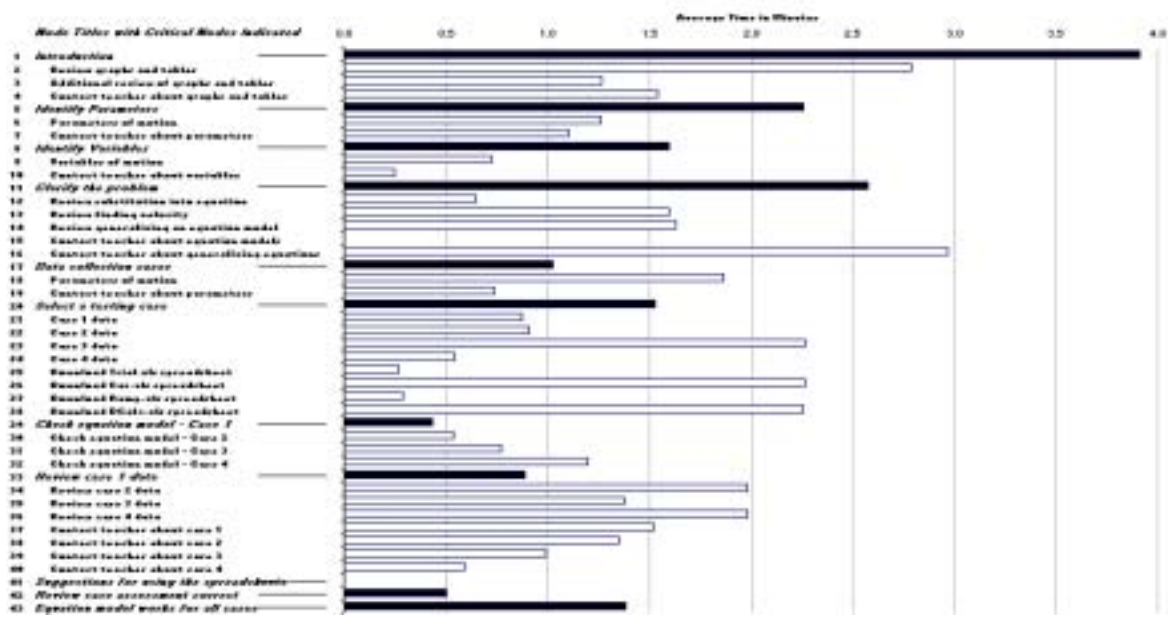


Figure 1. Average Time per Node, Male Students in Affinity Learning

Average Time Spent on Each Node - Males
Average amount of time all students spent on the node
Node cases: Average Time Spent

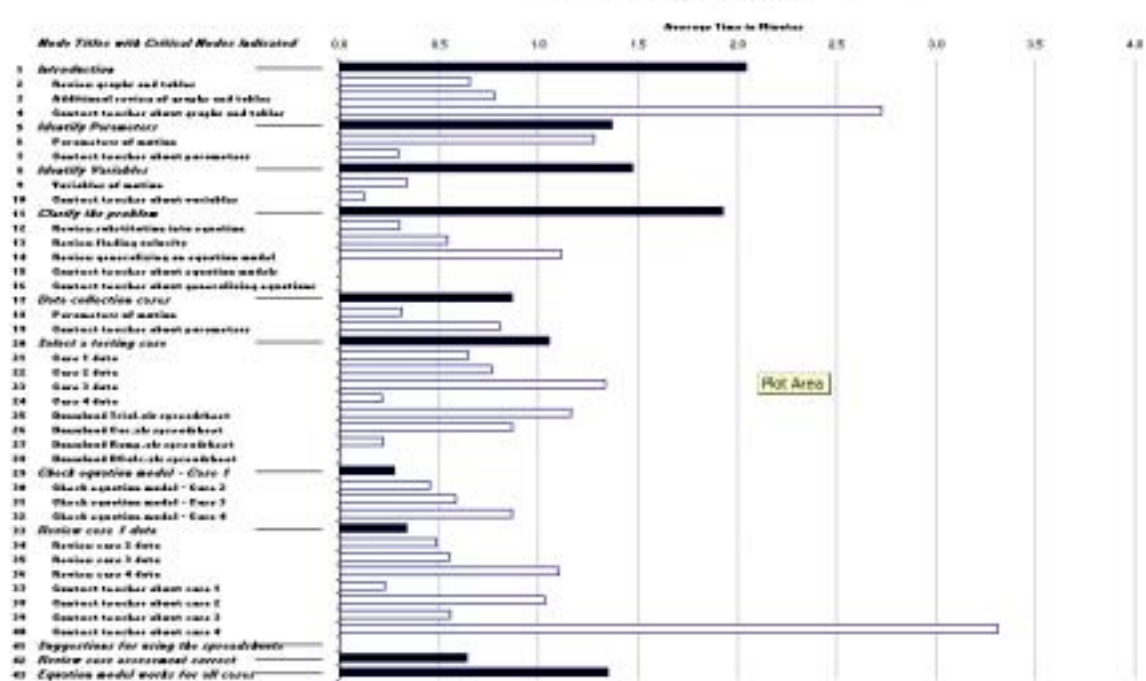


Figure 2: Average Time per Node, Male Students in Affinity Learning

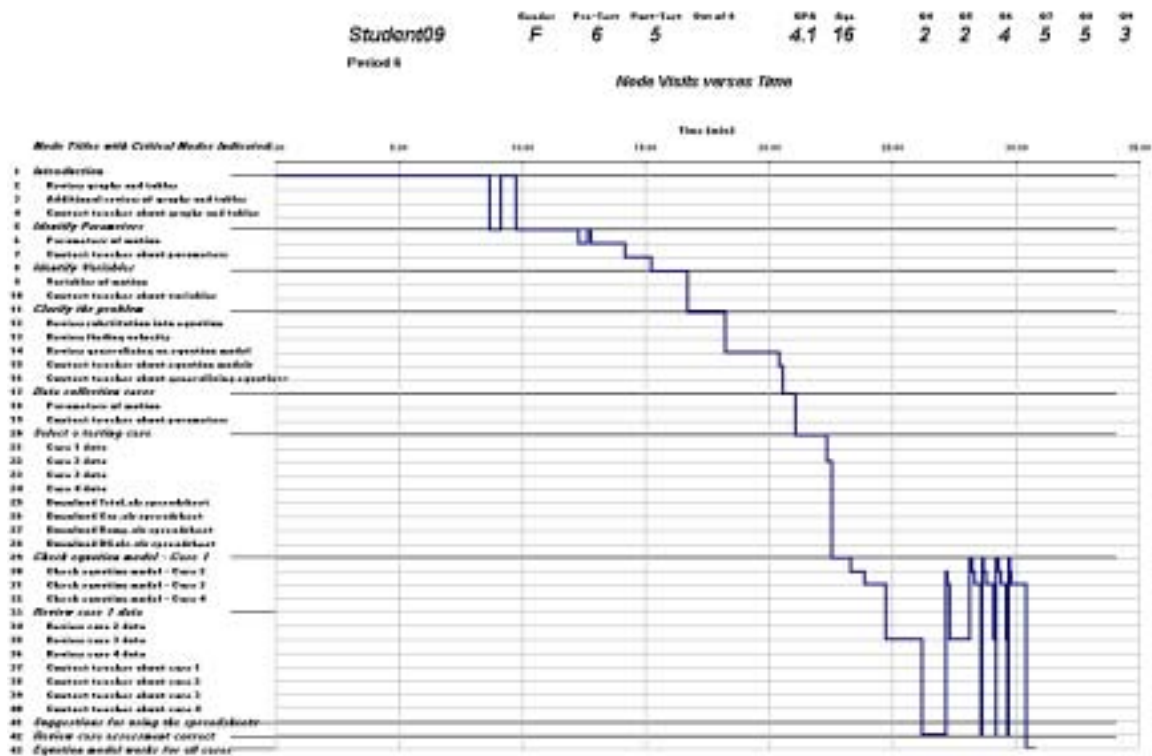


Figure 3: Female Student: Node Visited vs. Time in Affinity Learning

CRITICAL THINKING TOOL

In explaining the principle of social cognition, Collins, Brown, and Newman (1989) suggest that the positive effects of student interaction may arise from increasing learners' ability to reflect on their own conclusions in light of others' thoughts. Such reflection facilitates learner metacognitive activities (Brown & Campione, 1996), which in turn can promote re-evaluation and modification of understanding. This increased metacognitive activity is particularly apparent when learners use the material to be learned in the context of solving real world problems. Stahl (2000) suggests that participation in social interaction also may expose problems in the learners' mental representation of new information, with resulting disequilibrium instigating restructuring of mental representations. Interaction with others facilitates construction of more useful, internalized representations of the concept.

In the studies reported in this paper we focused on experimental manipulation of student interactions with other students' thinking in the context of the Critical Thinking (CT) tool. Lehman, Kauffman, White, Horn, & Bruning (2001), for example, have shown that certain kinds of exchanges between a distance-learning teacher and at-risk students can improve engagement of these students in web-based courses. Similarly, Scardamalia and Bereiter's (1996) research with CSILE (Computer Supported Intentional Learning Environments) has shown that sharing ideas in a community of online learners can promote learning. Pragmatic principles that normally govern social interactions in face-to-face settings (e.g. Grice, 1975), however, may be compromised in online settings.

The current studies explored the instructional value of selected dimensions of social interaction in two web-based instructional units for undergraduate teacher education students. One unit focused on norm-referenced tests (NRT) and the second on classroom motivation (MOT). We tested whether learners using the CT tool for student collaboration and interaction in the two units would increase their conceptual understanding and awareness of competing perspectives as a function of varied levels of interaction with other users' ideas. The experimental manipulation consisted of providing users with one of four levels of access to other users' response to "ThinkAboutIt" (TAI) questions, with the tool randomly assigning students to one of the four conditions.

In TAI activities, which are inserted periodically into instructional units, participants respond to a question with one of the three choices (a, b, or c) and then wrote a brief (2-5 sentence) justification of their choice. These design features were chosen for several reasons. Asking readers to explain why their choice is most appropriate should elicit the cause-effect relationships and inferences that are a part of their mental representation (Graesser et al., 1994; Kuhn, 1991). Additionally, research on text processing has found that self-explanations enhance deeper processing of text (Chi et al., 1994; Chi, 2000). Earlier studies in our center also had shown that users often skim on-line text, failing to attend to important concepts taught in the unit. Comments of students using pilot versions of the tool suggested that the TAI activity would greatly reduce this tendency.

When a student completes a TAI activity, the tool displays a dynamically generated “View Responses” page that constitutes the experimental manipulation. In the two studies reported here, depending on experimental condition, this page provided the user with one of four different levels of user-to-user interaction ranging from no interaction to the ability to rate and respond to other users’ answers. At Level 1, the page displayed the participant’s choice and rationale. At Level 2, participants viewed their own choice and rationale, plus a dynamically generated graph that showed what percentage of other users had chosen “a,” “b,” or “c.” At Level 3, participants viewed all features of Level 2 plus the rationales other users had used to justify their answers. At Level 4, participants viewed all features of Level 3 and were asked to rate the quality of five rationales and comment on at least one. This condition was considered to be the highest level of interaction because participants were exposed to a variety of viewpoints and actively evaluated the merits of these arguments. The MOT study, which followed the NRT study, differed primarily in having a reduction in online text and twice as many TAI activities (8) as in the NRT unit (4).

Results

Table 1 presents mean scores on knowledge, estimated time spent, self-efficacy, and critical thinking. Both units produced large and significant gains ($p < .01$) in knowledge and self-efficacy. The latter is particularly interesting in that it is a measure of confidence in using or applying the content to test interpretation and classroom management. On the other hand, the experimental manipulation of levels of interaction produced no changes in any of our measures: knowledge, self-efficacy for using information provided by the unit, or critical thinking. Time spent tended to increase as a function of level; this difference approached significance. Higher levels of knowledge, efficacy, and critical thinking were significantly associated ($p < .01$) with time spent in NRT but not the MOT unit.

Table 1. Means and Standard Deviations for Norm-Referenced Test (NRT) and Classroom Motivation (MOT) Units.

Variable	Level 1	Level 2	Level 3	Level 4
Norm-Referenced Test Unit				
Knowledge pretest	6.10	6.30	6.82	6.24
Knowledge posttest	13.10	12.56	13.55	12.12
Time between TAI submissions	2020.87	2223.48	2184.83	2909.95
Self-efficacy pretest	25.33	24.93	26.82	27.16
Self-efficacy posttest	34.04	33.26	35.31	33.32
Critical thinking assessment	2.88	2.54	2.73	2.57
Classroom Motivation Unit				
Knowledge pretest	7.46	7.65	6.93	7.42
Knowledge posttest	13.00	12.92	13.00	12.73
Time between TAI submissions	1326.13	1234.36	1115.00	1749.08
Self-efficacy pretest	31.62	31.46	30.00	30.53
Self-efficacy posttest	36.15	34.19	34.07	33.11
Critical thinking assessment	3.23	2.78	2.64	2.39

User’s written comments about both units were predominantly positive, with more than half of the comments on the “suggestions to make the site better” question stating that the site needed no changes. TAI questions and feedback from viewing other user’s comments were cited as the most interesting parts of the units. Most users cited providing a rationale for their answers as what they liked most about the TAI questions, stating that it caused them to think about why they had chosen an answer. Slightly fewer mentioned either the ability to see other’s responses to the question or the ability to share opinions as being a feature that they liked. Suggestions for improvement focused on content, activities, and navigation.

DISCUSSION

The Affinity Learning tool demonstrates the use of an electronic tutoring technology that interacts with both teacher and student and “grows” to provide a comprehensive and personalized learning experience. The Affinity environment captures the skills of a master teacher in a dynamic but simple technical embodiment and presents lessons and assessments online to a student. The student data from Affinity indicate not only learning is occurring, but also provide fine-grained analysis of progress and give interesting insights into the learning process itself.

The CT tool demonstrates how a technology can allow students to share information on choices and rationales. Data showing overall gains in participants' knowledge and self-efficacy provide evidence that these activities can produce effective learning and understanding. Correlational data further not only show relationships between time spent in learning and basic knowledge acquired, but also with efficacy and critical thinking, suggesting that web-based instruction has possible utility for promoting critical thinking and application. The finding of no differences among different forms of feedback are interpreted in light of the lack of a true control in these studies; all conditions involved student justification of choices. In new studies currently underway, the tool has been refined to include this condition and to further enhance motivation and communication among students

These studies and our general approach to this research are designed to advance our understanding of features of web-based instructional technology that promote learning and enhance motivation. Of particular importance to educational research and instructional design is the accomplishment of conducting quasi-experimental and true experimental studies (e.g., with random assignment, dynamically generated variation of instructional material, and automated data gathering), while also delivering an educationally viable treatment. Experimental-educational units such as these can enable researchers to empirically validate web-based instructional design principles, while simultaneously providing the basis for ongoing improvement of instructional approaches. Based on our findings, we are continuing to revise both the Affinity Learning and Critical Thinking tools to improve their functionality with respect to instructional design, contextual, and social interactive characteristics. We also are continuing to work to simplify navigation, to refine content and presentation (e.g., by replacing text with visual and interactive instructional materials), and to improve the quality of assessments in both Affinity and the Critical Thinking tools.

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