A Dynamically Adaptive TutorIT Tutorial in Basic Statistics

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This study examined the effectiveness of a dynamically adaptive TutorIT tutorial for graduate students’ learning of basic statistical skills and their attitudes toward this tutorial. Fifteen in-service teachers interacted with the tutorial. As hypothesized, all who completed the tutorial demonstrated mastery. However, the class differed dramatically in their readiness for the material. 46.6% of the teachers could not finish the tutorial. The tutorial completion rates were considerably lower among teachers with a non-mathematical background. A follow-up analysis of the tutorial question difficulty ratings revealed that higher thinking level questions were too complex. Future research should represent the knowledge to-be-acquired hierarchically to make contact with the weakest student prerequisites.

Keywords: TutorIT, EZauthor, AuthorIT, intelligent tutoring systems, adaptive learning, dynamically adaptive tutoring systems, learning statistics

INTRODUCTION

This report presents preliminary findings of a study using a simplified version of the AuthorIT authoring system, called EZauthor, to develop a TutorIT tutorial in basic statistics. TutorIT was then used to provide graduate
in-service teachers with adaptive tutoring on this material (Scandura, 2011, 2013a,b).¹

The AuthorIT authoring system is based on the Structural Learning Theory (SLT) (cf. Scandura, 1971, 2007). The method of Structural (domain) Analysis (SA) in SLT is used to represent the knowledge students are to master. This to-be-acquired knowledge is represented hierarchically at multiple levels of abstraction. The refinement process continues with arbitrary degrees of precision until contact is made with prerequisite skills available to even the weakest members of the given student population. The resulting knowledge representations enable TutorIT to make all tutoring decisions automatically. TutorIT delivers dynamically adaptive tutoring (AKA Intelligent Tutoring Systems) for each and every student in the targeted population – without programming.

TutorIT presents the student with selected test items and/or guidance. TutorIT infers what the student does and does not know about what must be learned for success. Immediate feedback is given designed to help the student progress as would a good human tutor. TutorIT dynamically adapts to each individual student’s needs at each point in time. The process continues until the student either masters the content to a pre-specified level of mastery, or gives up.

AuthorIT has been used by the original development team to develop and TutorIT to deliver a wide variety of adaptive tutorials covering basic math skills ranging from whole number arithmetic to algebraic equations (see Scandura, 2011, 2013s), and critical reading. Sample tutorials range from algebra word problems to the periodic table in chemistry.

Unlike the full AuthorIT system, EZauthor is designed to facilitate development of TutorIT tutorials covering broad domains of relatively unstructured content. It is well suited for content consisting of wide varieties of more or less related test items. These are task domains that have not been subjected to systematic Structural (cognitive task) Analysis (Scandura, 2007, 2011). The format of such content, however, may vary considerably. It may include a wide variety of test items, including multiple choice items involving any number of correct and/or incorrect choices, fill-in the-blank questions, clicking in specified regions or even self-evaluation. These capabilities make EZauthor particularly useful in

¹ For more details on AuthorIT and TutorIT please see Scandura (2013a) http://www.tutoritweb.com/Articles/White_Paper_on_AuthorIT_and_TutorIT.pdf, TutorITweb.com. I also would like to thank Prof. Scandura for his comments on various drafts of this article and especially his help in clarifying how AuthorIT could be used in future research to hierarchically analyze complex task domains (US Patent 8,750,782, June 14, 2014).
constructing TutorIT tutorials for essentially any kind of test preparation. In each case, TutorIT takes this information as input and automatically delivers the material to individual students, making all diagnostic and tutoring decisions automatically, and continuing through mastery.

This study is the first time EZauthor (or any AuthorIT system) has been used independently of the original development team. Specifically, the author used EZauthor to develop a TutorIT tutorial covering basic statistics skills for graduate in-service teachers. Possessing sufficient statistics skills is crucial for graduate in-service teacher abilities to critically examine educational research findings, analyze and interpret standardized assessment results, and develop and evaluate classroom assessments. However, learning statistics can be particularly challenging for students with a non-mathematical background like arts and music, preschool, language arts, or physical education teachers (Oliver, Pisano, Alonso, & Roca, 2006). Students with a non-mathematical background usually have a lower readiness for learning statistics, which consequently hinders their statistics performance. As a result, the students tend to develop knowledge gaps that impede their academic performance in more advanced graduate courses. What makes dynamically adaptive tutoring method particularly suitable for enhancing graduate in-service teachers’ basic statistics skills is its ability to quickly identify gaps in students’ prior statistics knowledge and potentially adapt to their needs during the tutoring process.

To assess the effectiveness of this tutorial, I administered this tutorial as an extra credit assignment in my online class in Educational Assessment. In addition to assessing its effectiveness, I collected student reactions to the tutorial. In this report, I first describe the method used to develop my TutorIT statistics tutorial, along with the process used and the resulting tutorial. Second, I describe the method used in conducting the experimental study, followed by the results and discussion thereof. Finally, I summarize my conclusions and options for future research.

**USING EZAUTHOR TO DEVELOP THE STATISTICS TUTORIAL**

In order to develop an adaptive TutorIT tutorial in basic statistics I used the EZauthor AuthorIT authoring system. Since I did not have any prior knowledge or experience in any AuthorIT system, I worked closely with the original development team to gain a basic understanding of the EZauthor authoring principles at the beginning steps of the tutorial development. The process of authoring a tutorial using EZauthor is very similar to other authoring systems like Captivate,
for example. However, a few EZauthor features are somewhat different. For instance, the screen for designing an EZauthor question has an area for feedback and help on-demand. What to include in each of these areas is up to the EZauthor author. While these features are not unique to the EZauthor system, the way TutorIT delivers questions is quite unique. Thus, when a student receives a question, she/he can click on the help button to receive information on how to solve the question. If the student does not answer the question correctly, she/he will receive feedback and TutorIT will continue the tutoring process coming back to missed items until the student masters the entire list. The process of returning to missed items requires the EZauthor author to carefully consider what information to include in the help and feedback areas to support learners to master the learning content without providing answers directly and, at the same time, sufficiently motivate them to continue the tutoring process through mastery. After experimenting with the EZauthor system and exploring its options and abilities for a while, an EZauthor author can develop sufficiently long tutorials in a relatively short time.

My tutorial included 25 questions that focused on the application of basic statistics skills for classroom and standardized assessment. Specifically, it focused on the following statistics concepts: Mean, median, mode, range, standard deviation, variance, variability, and normal distribution. The tutorial content was not developed using Structural Analysis. Rather, it included whole questions (as in most learning systems) at factual, conceptual, and application/analysis levels for the statistics skills to-be-learned (Bloom, 1956). The analysis and some of the application questions required higher level thinking and involved considerable computation.

USING TUTORIT TO DELIVER THE STATISTICS TUTORIAL

Experimental Method

Participants
Fifteen in-service teachers enrolled in a graduate online course in Educational Assessment at an East South Central public university participated in the study. Among them were 12 females and three males. All participants had completed a graduate introductory statistics course during their prior coursework. Table 1 presents a percentage distribution of the participants’ teaching area.
Instruments

Statistics Learning

TutorIT automatically scores students’ answers and saves their scores in the system as students proceed with the TutorIT statistics tutorial.

Student Motivation and Attitudes toward the Tutorial

Student motivation and attitudes toward the TutorIT statistics tutorial were assessed using a simplified version of the Instructional Material Motivation Survey (IMMS) instrument (Song & Keller, 2001). The IMMS instrument includes four different sections examining attention, relevance, confidence, and satisfaction (ARCS). The simplified IMMS instrument included 16 items, where each of the four ARCS components was operationalized by 4 items. Students responded on a 5-point Likert-type scale with response choices: 1 (not true), 2 (slightly true), 3 (moderately true), 4 (mostly true), and 5 (very true). Sample questions were, “The way that the content of the tutorial was introduced got my attention” (A); “I could relate the content of this tutorial to things I have seen, done, or thought about in my own life” (R); “The way that the information was organized made me feel that I could be successful in the tutorial” (C); and “It was a pleasure to work on such a well-designed tutorial” (S). In addition, students were asked to answer two open-ended questions indicating what they liked or disliked about the tutorial.

Procedure

Students completed all activities online as an extra credit assignment. After completing the TutorIT statistics tutorial, the participants filled out the IMMS and open-ended questions where they reported their attitudes toward the learning materials.
RESULTS

Six students completed the tutorial and received 100%. Another two students completed the tutorial but their TutorIT scores were lost due to a technical glitch. Among the eight students who completed the tutorial, four students taught high school mathematics and family and consumer science, and middle school mathematics and technology. The other four students were elementary school teachers. The rest of the students scored below 40% correct. They were preschool, elementary, arts and music, physical education, and language arts teachers.

The analysis of students’ IMMS responses revealed moderately high Attention, Relevance, Confidence, and Satisfaction levels ($M_{Attention} = 3.47$, $M_{Relevance} = 4.33$, $M_{Confidence} = 3.67$, $M_{Satisfaction} = 3.71$, $M_{Total} = 3.79$), indicating that the tutorial was particularly relevant and, overall, students were satisfied with their TutorIT learning. Students’ open-ended responses showed that students liked the following:

- Amy, an elementary teacher, TutorIT score 100%: I liked how the tutorial gave me the same questions until I was successively able to answer with the correct answer. I also liked how it informed me of how many correct answers there were for several of the questions. The explications were also clear and helpful.
- Josiah, a middle school mathematics and technology teacher, finished TutorIT but the score was lost due to a technical glitch: I liked how the tutorial was user friendly and easy to progress through the lesson. I thought the text was well arranged and easy to read and follow. The voice explanations were also helpful. The color charts and standard deviation curves were easy to follow.
- Olivia, a high school family and consumer sciences teacher, TutorIT score 100%: I liked the feedback given and the helpful hints.
- Kim, an elementary teacher, TutorIT score 100%: The self-pacing aspect of it was nice.
- Jessica, a high school mathematics teacher, TutorIT score 100%: Repeating questions for mastery.

Even though the tutorial covered basic statistics skills that were taught in the introductory statistics course, which all students had already completed, many students commented that the tutorial questions were too difficult:

David, a middle school language arts teacher, TutorIT score 28%: TOO much difficult math!!
Elizabeth, an elementary school teacher, did not succeed to finish the tutorial: Explain each topic prior to that particular section of questions…

DISCUSSION

The results demonstrate that TutorIT tutorials can guarantee mastery of broad ranges of material. Specifically, a combined analysis of student background, TutorIT scores, and responses to open-ended questions confirmed the following:

1) Anyone who finished the tutorial demonstrated mastery (100% or close to it).
2) Most of the students with a mathematical background finished the tutorial.
3) The class differed dramatically in their readiness for the material. Those students who did not finish were perhaps less motivated or found the tutorial too difficult. The wide variety of student backgrounds in the class can possibly explain why some students found the tutorial too difficult. This finding is in line with our expectation that students with a non-mathematical background are likely to develop gaps in their prior statistics learning, which possibly hampered their progress with the tutorial (Lane & Tang, 2000; Mills, 2002; Novak, 2014).
4) Some students persisted and succeeded, others did not.

Given that 46.6% of students did not finish the tutorial, it was important to examine the reasons behind student failure to finish the tutorial. The question is not whether a student who completes a tutorial will master the material. The question is whether they will have sufficient time and/or motivation to compete the given tutorial. The likely reason many students did not complete the tutorial was due to dramatically different levels of preparation together with the widely varying complexity of the material, some requiring considerable computational skills that many did not have. In order to confirm this assumption, I conducted a follow-up analysis of the tutorial learning content.

A FOLLOW-UP ANALYSIS OF THE LEARNING CONTENT

Students who participated in the study were asked to rate all tutorial questions on a 5-point Likert-type scale as to difficulty. The response choices included: 1 (Very Easy), 2 (Easy), 3 (Neutral), 4 (Difficult), and 5 (Very Difficult). Five students participated in this activity.
The analysis of question difficulty ratings (Table 2) revealed that, on average, students had a good factual, conceptual, and application knowledge of mode, mean, median, and range statistics concepts. However, higher thinking level questions (analysis knowledge) on these concepts were relatively challenging. Students had considerably more difficulties with standard deviation, normal distribution, variance, and variability concepts even at the factual and conceptual levels. Particularly difficult were questions requiring higher thinking on normal distribution and standard deviation concepts.

**FUTURE RESEARCH**

As above, many of the questions were too complex for many of the students. One way to address this problem in future research would be to break down the complex questions into series of separate simpler tasks using EZauthor. In this case, each such task would either test component skills individually, or perhaps include a series of simpler tasks, each beginning where a previous one leaves off. This way, testing would consist of a series of simpler more or less self-contained steps each contributing part of a total solution.

A better way would be to subject complex questions that are too difficult to Structural Analysis (SA) (Scandura, 2007, 2011, 2013a). In this case, SA would be used to represent the knowledge students must learn for success hierarchically. SA begins with a (sub)domain of similar problems. The optimal solution is to systematically use AuthorIT’s knowledge representation tool to analyze the content hierarchically. SA begins by defining a representative problem in the domain,

**TABLE 2**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Factual Knowledge</th>
<th>Concept Knowledge</th>
<th>Application Knowledge</th>
<th>Analysis Knowledge</th>
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</table>
assigning names to the inputs and outputs and the operation describing the solution procedure. Patented methods (US Patent 8,750,782) are then used to systematically and successively refine these operations using a small number of refinement types. In our case, the process begins with a prototype TutorIT statistics problem. The goal is to represent the knowledge that needs to be acquired hierarchically.

Sample Problem: You scored a 24 on your ACT math test. The mean for this exam is 21, with a standard deviation of 3. On the math SAT test, the mean is 500 with a standard deviation of 50. If you had taken the SAT what would your score have been?

This problem involves scores, means and standard deviations on two sets of parallel exams. Some of the information is given and some missing. The goal in each case is to find the missing information. As Dr. Scandura explains, “AuthorIT would be used to systematically and successively refine this task into simpler operations and/or decisions. This will involve distinguishing various combinations of given and target information, identifying a solution process in each case and continuing the process by successively refining each sub-process.”

Learning Hierarchy

Given mean (M) and standard deviation (SD) on two equivalent criterion-referenced standardized achievement tests (Tests A and B) and Student’s Score (SS) on one test, compute equivalent S score on other test.

CASE Student Score (S)

Test A → Compute equivalent SS on Test B

Compute the number of SDs from M on Test A

\[(SS_A - M_A)/SD_A = \text{Number SDs on Test A}\]

Multiply SD_B by Number of SDs from M on Test A

\[SS_B = M_B + SD_B \times \text{Number SDs on Test A}\]

Test B → Compute equivalent score on Test A

Compute the number of SDs from M on Test B

\[\ldots\]

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2 Personal Communication

3 This sample learning hierarchy describes only the minimum required computational tasks to solve the problem. It could be further refined and generalized to include as many prerequisite skills as needed.
Irrespective of whether a domain is analyzed using EZauthor or AuthorIT, TutorIT will interact with students, ensuring that any who finish will in fact demonstrate mastery. In future research, SA should ideally be continued until the resulting knowledge representation makes contact with prerequisites that may be assumed to be available to even the weakest students in the targeted population. Associated questions, instruction, and feedback attached to elements in the resulting hierarchy should sufficiently motivate students to finish.

REFERENCES


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4 BTW, the answer is 550.
EDITORIAL NOTE

Due a major disconnect in paradigms, many ITS researchers have a basic misconception of SLT and the now proven benefits in developing and delivering dynamically adaptive tutoring systems (aka ITS). TutorIT tutorials as well as the AuthorIT authoring systems used to develop them are fundamentally different from methods used to develop and deliver traditional ITS.

ITS development is based on the assumption that it is essential to understand how students actually learn things. In an important sense, SLT is a more comprehensive theory concerned not only with learning but with teaching as well. Teachers in SLT need care less about differences between how experts and novices solve problems. Teachers know they do things differently. Among other things experts can deal with bigger chunks of knowledge. They get to the result far more quickly and/or effortlessly. It is not how students learn that matters. Rather, it is what they know at each point in time that determines what the teacher (or automated TutorIT tutoring system) should do next, whether that be test or teach.

To make this possible, we have found a way (based on SLT) to make it possible to deal with all knowledge based on a uniform, highly systematic hierarchical and now patented method to represent knowledge. Knowledge potentially assessable to both experts and novices, as well as everything in between is represented hierarchically, simultaneously at all levels of abstraction.

The focus in SLT, and AuthorIT and TutorIT based thereon, is on what subject matter and instructional design experts (SMEs) believe must be learned for success, irrespective of whether students are experts, novices or any place in between. Using methods first revealed and reduced to practice in our patent AuthorIT technologies, SMEs are taught to represent knowledge hierarchically, simultaneously at ALL levels of abstraction.

These new methods make it possible to avoid the complications cognitive psychologists have faced since its inceptions. The concern with how experts, naïve etc. people solve problems is inherently limited – precisely because there are any number of gradations and variations. The solution implemented in AuthorIT and used in TutorIT is to represent all levels of expertise simultaneously. Doing this, among other things, dramatically simplifies the task of building and delivering dynamically adaptive tutoring systems (Scandura, 2013a, US Patent 8.).