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# AN EXPERIENTIAL APPROACH TO TEACHING AND LEARNING PROBABILITY: STAT LADY


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This paper describes Stat Lady -- an experiential approach to teaching and learning probability based on the postulate that learning is a constructive process, fostered by an experiential learning environment that is anchored in real-world problems. Two experiments are discussed, comparing learning from Stat Lady vs. more traditional approaches -- classroom lecture, and paper-and-pencil workbook. Findings showed that Stat Lady learners performed at least as well on the outcome tests as the Lecture and Workbook groups despite the presence of many factors strongly favoring the traditional conditions. In some cases, Stat Lady subjects greatly exceeded the performance of the other groups.

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## PREFACE

We would like to thank our *Stat Lady* programmers: Trace Cribbs, David Logan, Rich Walker, and April Bremner. We'd also like to thank those people who helped make the experiments run smoothly: Bob Young, Clarke Burnham, Cathy Connolly Gomez, Linda Robertson-Schüle, Wayne Crone, Pam Goettl, and Kevin Kline.

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## SUMMARY

This paper describes *Stat Lady,* an experiential approach to teaching and learning PROBABILITY based on the postulate that learning is a constructive process, fostered by an experiential learning environment that is anchored in real-world problems. Two experiments are discussed, comparing learning from *Stat Lady* vs. more traditional approaches -- classroom lecture, and paper-and-pencil workbook. Findings showed that *Stat Lady* learners performed at least as well on the outcome tests as the Lecture and Workbook groups despite the presence of many factors strongly favoring the traditional conditions. In some cases, *Stat Lady* subjects greatly exceeded the performance of the other groups.

# AN EXPERIENTIAL APPROACH TO TEACHING AND LEARNING PROBABILITY: STAT LADY

## INTRODUCTION

If Statistics were an elective course, not many students would choose to take it because of a prevailing prejudice that it is difficult, boring, and/or worthless. Statistics textbooks do little to dispel this negative image -- alien symbols, formulas, and complex terminologies abound within banal examples. But there's so much more to Statistics than memorizing complex formulas. To test our belief that this negative attitude could be turned around using an experiential instructional approach, we developed *Stat Lady* (see Figure 1).


**Figure 1**
***Stat Lady* Presenting a Probability Problem Involving T-shirts**

### Theoretical Basis

*Stat Lady's* development was based on the tenet that learning is a constructive process, which may be improved with student involvement (i.e., experiential learning), and further enhanced when instruction is situated in real-world examples and problems. The constructivist approach posits that learners come to new learning situations already possessing knowledge structures which can be used as a sort of *cognitive loom* on which to interweave new knowledge and skills (Bartlett, 1977; Drescher, 1991; Piaget, 1954). Moreover, there is a lot of support in the learning literature for the notion that knowledge lasts longer because the experience (i.e., "doing" rather than "receiving") fosters cognitive growth and structure, and is also more intrinsically motivating (Coleman, 1976; Lehrer & Horvath, 1993; Shute & Glaser, 1990; Spencer & Van Eynde, 1986). In addition, results from research on situated cognition have found that learning is optimized when instruction is anchored in interesting and real-world problem-solving environments (Brooks, 1991; Brown, Collins, & Duguid, 1989; Clancey, 1992; Collins, Brown & Newman, 1989; Lave & Wenger, 1991; Suchman, 1987; The Cognition & Technology Group at Vanderbilt, 1992). Given these theoretically sound premises, what are some of the research issues *Stat Lady* can address?

*Stat Lady* supports (and actually requires) active learning, and lecture environments are rather passive, so our first question examines the contribution of activity in the learning process, especially as it relates to learning outcome. The second question we explore in this paper has to do with the fact that computers have become increasingly important as educational tools, from Kindergarten applications on upward. Each year, we see a little more learning taking place in front of computer screens and a little less in front of teachers and blackboards. But what (and by how much) does the computer actually contribute to learning, beyond traditional instruction? Putting these two basic research questions together, we can ask: If you delivered the identical curriculum in different formats (e.g., on a computer, by a teacher in a lecture, or from a workbook) and assessed learning outcome, would there be group differences? Or might we see differential patterns of learning dependent on learner characteristics (i.e., aptitude-treatment interactions)? Another possibility is that individuals may show comparable learning outcomes, but differ in terms of enjoyment of the learning experience.

## Computerized Instruction: *Stat Lady*

*Stat Lady* instructs a range of topics in introductory Statistics (Shute & Gawlick-Grendell, 1992). However, our focus in this paper is only on the 3-hour probability module. The curriculum included in this module resulted from our inspection of six introductory Statistics textbooks, and extraction of the most commonly instructed probability issues. Because textbooks differ in terminology and symbols, we settled on the most common representations for *Stat Lady's* instruction. The range of the curriculum starts with basic concepts (e.g., elementary event, sample space) and ends with complex skills (e.g., computing the binomial expansion).

The tutor was designed to reflect the premise that learning should be based on prior, familiar knowledge, presented in an interactive, *grabbable* format that contains interesting examples from the real world. To illustrate how these notions are incorporated into the tutor, the program begins with *Stat Lady* engaging the learner in a "betting game." Learners are provided with $5.00 electronic cash, and bets are rendered on different combinations of numbers. A particular game is defined (e.g., *Stat Lady* wins if she gets a 9 or 10 on a roll of two dice, the learner wins if an 11 or 12 shows up, otherwise, it's a draw). The learner then makes a bet (from "no bet" up to $5.00) and left-buttons on the option "ROLL 'EM" which causes *Stat Lady* to shake and roll two dice. Over time, and usually a loss of cash, learners will realize that most of the games that *Stat Lady* proposes are unfair (to the learner). To prove this, they must construct a table listing all two-dice events (2, 3, ... 12), all possible *outcomes* corresponding to each event (e.g., {1,1} {1,2 or 2,1} ... {6,6}), and all associated probabilities. Learners are then able to precisely assess the "fairness" of the games (e.g., figuring out the probability of obtaining a 9 or 10 = 7/36 vs. an 11 or 12 = 3/36). Thus, *Stat Lady* empowers and encourages learners, using real-world examples for problem-solving scenarios rather than simply providing formulas to memorize or tables of numbers to manipulate. Concepts to be learned are embedded in familiar situations (to draw on prior knowledge), and examples vary sufficiently to show the range/limits of applicability.

In addition to basing instruction on fun and familiar examples, we believed that *Stat Lady's* colorful, graphic displays would also motivate learners (e.g., she has a large wardrobe of problem-relevant costumes, such as a chef's outfit for a problem set on pizzas, and a Las Vegas dealer's outfit for playing "Stat Craps"). Other features of the tutor include animation (e.g., *Stat Lady* shuffles and deals cards, flips coins, etc.) as well as speech and sound effects. For example, after getting an answer correct, *Stat Lady* may say, "Oh, isn't that special?!" or there may be a drum roll that accompanies *Stat Lady* cart-wheeling across the screen (for really hard problems).

Unlike human teachers, *Stat Lady* is consistently good-natured and interactive -- talking with learners, not at them. Furthermore, she provides immediate and pertinent on-line support, giving context-sensitive feedback in response to problem-solving activities. For instance, if a learner incorrectly answered a problem with the SUM of two probabilities (rather than the product), *Stat Lady* would respond that, "It looks like you used the Addition Rule, but you should have used the Multiplication Rule in this problem..." A "Probability Dictionary" is always available, consisting of a listing of relevant probability concepts and rules. For each entry, the concept is defined and an example is provided. Bold-faced words within definitions are also accessible, in a hypertext format. Other support features of the tutor include an on-line Formula & Rule Reference Book and calculator.

**Learning Outcome Measure**

The degree to which we can accurately assess learning depends on the quality of the learning outcome measure(s). We translated each of *Stat Lady's* curricular elements into questions on two outcome tests (i.e., parallel forms -- A and B). Two forms were developed so that we could counter-balance tests in studies involving *Stat Lady*, half of the Ss in each experimental condition receive Form A as a pretest, Form B as the posttest, and the other Ss receive the opposite ordering. Every item on Form A had a matched item on Form B. Each form of the test contained 26 items, with some items having subparts.

We classified each test item into one of two categories: Declarative knowledge and Procedural skill. The Declarative knowledge items were defined as those items requiring the retrieval of a statistical concept or definition for problem solution. Procedural skill items required the application of some probability formula for solution. Reliability measures and a detailed description of the two forms can be found in Shute, Gawlick-Grendell, & Young (1993).

## Affective Measure

Earlier, we suggested that individuals may show similar learning outcomes, but differ in terms of their enjoyment of the learning experience. To gauge this affective factor, at the end of Experiment 1, we asked all Ss to write down their comments about what they liked and did not like about their learning experience. In Experiment 2, we administered a more formal survey to all Ss addressing issues related to subjects' enjoyment of their learning experience, preferences for various learning environments, whether they felt they learned something, and so on. Because these data were anonymous, we could not join them to actual outcome data, but we did have information about the conditions under which the respondents had learned.

## Experiment 1

The first study compared learning from *Stat Lady* vs. a traditional, college lecture covering the same curricular elements. We examined learning differences as a function of learner *activity* level: Does instructional method (*Stat Lady* - active vs. Lecture - less active) produce differential learning outcomes? We included a third condition, no-treatment control, to provide a measure of baseline test-retest changes.

Subjects were first-year students enrolled at the University of Texas, Austin. They participated in the experiment for Psychology course credit. Subjects were assigned to one of three conditions -- *Stat Lady,* Lecture, or Control. All Ss were administered the pretest on the first day, then Ss in the two experimental conditions received three hours of instruction (from either *Stat Lady* or a college professor), one hour at a time, across three days. On the fifth day, the posttest was administered to Ss in all conditions. Aptitude (e.g., Verbal and Quantitative SAT scores) and demographic data were also collected from the Ss. A detailed description of the experiment can be found in Shute, et al. (1993).

In terms of the main effect of condition on learning outcome, we found that both treatment conditions produced large pretest to posttest changes in scores, yet did not differ from one another (Shute, et al., 1993). We viewed these data as encouraging for several reasons. First, there was the experience factor. The professor delivering the lectures had more than 20 years of experience teaching this subject matter, while *Stat Lady* was on her very first teaching assignment. Second, there was the familiarity issue. College students are considerably more familiar with the lecture method of instruction than with having lessons delivered solely from a computer. Thus, Ss in the *Stat Lady* condition were at a disadvantage because, not only did they have to learn new knowledge and skills (probability curriculum), they also had to learn to get around in an unfamiliar learning environment.

Next, we tested the interaction between condition and type of knowledge acquired (i.e., declarative and procedural). This interaction was significant, $\underline{F}\,(2,165) = 5.87$, $p < .01$, and can be seen in Figure 2.

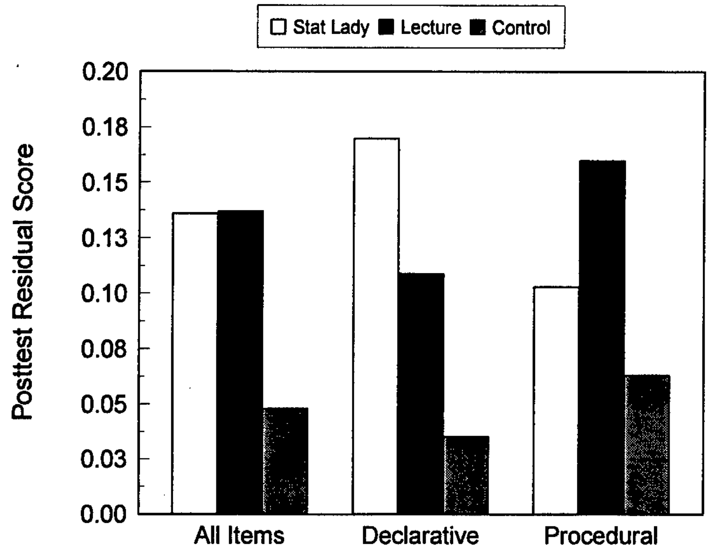


**Figure 2**
**Different Types of Learning Outcome**
**by Treatment Condition**

First, Ss in the *Stat Lady* condition performed significantly better on declarative knowledge posttest items compared to Ss in the Lecture or Control groups. On the other hand, Ss in the Lecture group appeared to acquire procedural skills better than either the *Stat Lady* or Control groups. The *Stat Lady* advantage for acquiring declarative knowledge was straightforward. However, the procedural skill advantage for Ss in the Lecture group was equivocal because: (a) Lecture Ss (by chance) demonstrated significantly higher Procedural skills on the pretest than Ss assigned to the other conditions, (b) Lecture Ss also showed an incoming math advantage (i.e., higher quantitative SAT scores) than the other groups, and (c) The three-hour instructional time limit represents initial learning, typically declarative in nature. We tried to control for differences in incoming procedural skills by using residualized posttest data in our analyses, but the differential math advantage of the Lecture group may still have affected the results.

We also tested for an aptitude-treatment interaction between SAT scores and treatment condition, hypothesizing that high-aptitude Ss would perform better in the *Stat Lady* environment given a greater adroitness in adapting to novel circumstances, while low-aptitude Ss would be more comfortable in (and hence learn better from) the familiar Lecture environment. A multiple regression analysis was computed predicting outcome performance (posttest residual scores) from Condition, SAT score, and the interaction between the two. Results showed all variables were significant predictors of post-residual: Multiple $R = .51$,

$F\ (3,143) = 16.41$, $p < .001$. The interaction alone accounted for 4.4% of the unique variance ($F\ (1,143) = 8.45$, $p < .01$). Expected values were computed directly from the regression equation and plotted in Figure 3.

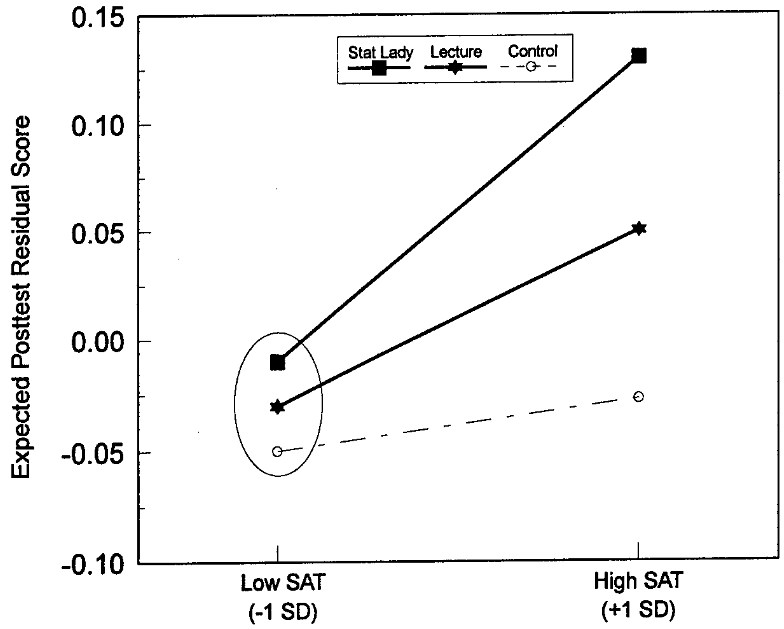


**Figure 3**
**Aptitude-Treatment Interaction**

As seen in Figure 3, high-aptitude Ss learned significantly more from *Stat Lady* than from the Lecture condition. However, low-aptitude Ss showed little difference among the three conditions (albeit, a slight *Stat Lady*, not lecture, advantage). One way to account for these findings is that high SAT students may have quickly acclimated to the new environment, enabling them to benefit almost immediately from *Stat Lady's* instruction. On the other hand, low-aptitude students may have had difficulty adapting to the novel *Stat Lady* environment. So, any potential instructional benefits may have been attenuated as the lows had to spend more time and cognitive energy learning to navigate within the unfamiliar environment.

## Experiment 2

The second study compared learning from the *Stat Lady* tutor vs. a paper-and-pencil instructional workbook of the *Stat Lady* materials. The primary question asked: How much more (if anything) does the computer contribute to learning? The *Stat Lady* tutor was used in this study, and the workbook was developed using the identical instructional text, graphical representations (i.e., screen dumps from the tutor), and problem-set items. Because there were three one-hour parts to the tutor, we developed three Instructional Workbooks, bound separately and administered one at a time. We also created three Answer Booklets (color-coded to match the associated workbook). The Answer Booklets reiterated problem statements, provided workspace for solving problems, and slots to write down final answers.

A Help Booklet was available at all times consisting of a paper-and-pencil version of *Stat Lady's* on-line Dictionary, Formula & Rule Reference Book, and Help for problems within each of the three parts. Finally, we created three Answer Keys, containing all of the correct answers as well as problem-specific feedback for each of the three workbook parts.

Subjects were obtained from a temporary employment agency, about half were male, and all were high school graduates. Before the study, Ss were randomly assigned to one of two treatment conditions: Workbook (N=104) and *Stat Lady* (N=107). The Workbook group received about 10 minutes of instruction on how to use the workbooks and coordinated booklets, which was about equal to the amount of time spent familiarizing *Stat Lady* learners with the computer environment (e.g., how to move the mouse around, view dictionary items, and so on). In addition, Ss in the Workbook condition were assigned calculators, a pair of dice, and other props to simulate the experiential learning environment underlying *Stat Lady*.

Experiment 2 was similar to Experiment 1 in the following ways: (a) Ss were allowed three hours to learn the Probability curriculum; (b) Ss reported differential familiarity with the two instructional environments (i.e., more familiar with workbooks than computer-administered instruction); and (c) Both groups were administered a one-hour pretest, followed by three hours of instruction (from the computer or workbook), then a one-hour posttest. What was distinct about this experiment was that: (a) All learning took place on the same day (rather than three separate days); (b) We fixed the order of curricular elements in the two treatments, and used the *identical* presentation style and problem sets, and (c) We tried to control learner activity (both environments were experiential) and only vary the format, or instructional medium (i.e., computer vs. paper-and-pencil). Another variable that differed slightly as a result of the format difference was the promptness of feedback -- Ss learning from the computer received immediate feedback, while Ss in the Workbook condition received slightly delayed feedback as they had to locate the proper section in the Answer Key to obtain feedback about solution accuracy (and reasons why). If learners answered an item incorrectly, they were instructed to redo it, just like Ss in the computerized *Stat Lady* condition. Several test administrators monitored the Ss to make sure they did not just go on to the next problem set.

Cognitive abilities were assessed with the CAM-4 battery of computerized tests (Kyllonen, Christal, Woltz, Shute, Tirre, & Chaiken, 1990) assessing the following cognitive abilities: working-memory capacity, information processing speed, inductive reasoning, associative learning, and procedural knowledge and skill. Information from these tests was used to investigate possible aptitude-treatment interactions.

Results from this experiment were as follows. We first compared learning by instructional approach. The pretest and posttest data are shown in Table 1 (overall and separated into Declarative knowledge and Procedural skill items). There were no differences between groups on <u>any</u> outcome measure: $\underline{F}$ (1,208) 0.40.

**Table 1**
**Pretest and Posttest Scores by Learning Condition**
**(overall, declarative, and procedural items)**

| STAT LADY CONDITION | OVERALL PRETEST | OVERALL POSTTEST | DECLAR. PRETEST | DECLAR. POSTTEST | PROCED. PRETEST | PROCED. POSTTEST |
|---|---|---|---|---|---|---|
| Computer (N = 107) | **27.2 (16.3)** | **39.4 (21.3)** | 43.2 (20.1) | 53.1 (25.7) | 18.8 (18.2) | 32.2 (21.6) |
| Workbook (N = 104) | **26.5 (14.3)** | **37.0 (19.1)** | 43.2 (21.4) | 50.1 (24.1) | 17.6 (14.4) | 30.1 (18.8) |
| F-Test | **0.13 (NS)** | **0.75 (NS)** | 0.00 (NS) | 0.75 (NS) | 0.26 (NS) | 0.57 (NS) |

Notes. Means are shown in columns; standard deviations in parentheses. The F-test compares the two groups.

The test-type (Declarative vs. Procedural) by learning-condition (Computer vs. Workbook) interaction was also not significant: $\underline{F}$ (1,208) = 0.01. Next, we examined the data for aptitude-treatment interactions, hypothesizing that high-aptitude Ss would perform better in the computerized version of *Stat Lady*, while low aptitude Ss would perform better in the traditional paper-and-pencil environment. For each cognitive ability listed above, as well as a general aptitude factor (resulting from the extraction of a single factor from the six cognitive measures), no significant ATI was found.

Finally, we analyzed the survey data to see if there were group differences in terms of how Ss felt about their learning experiences. Responses were anonymous to insure honesty. Each item in the survey was rated on a five-point scale (from strongly agree to strongly disagree), such as: Was this an ENJOYABLE EXPERIENCE? Do you feel that you LEARNED ANYTHING? Were the INSTRUCTIONS CLEAR? and so on. The following four (out of 10 possible) variables showed significant group differences: FUN:(*Stat Lady* Ss had more fun learning compared to the Workbook Ss), ENJOYABLE EXPERIENCE (*Stat Lady* Ss enjoyed their learning experience significantly more than the Workbook Ss), CLEAR INSTRUCTIONS (*Stat Lady* Ss perceived their instructions were clearer than the Workbook Ss), and BENEFICIAL HELP (*Stat Lady* Ss rated the tutor's help as being more beneficial than Workbook Ss). Thus, although the two groups actually ended up learning the same material to the same degree, the *Stat Lady* group had much more fun, and perceived the tutor to be clearer and more helpful than the Workbook group.

## DISCUSSION

*Stat Lady* was designed to make learning Statistics more meaningful and memorable. We sought to achieve this goal by embedding the curriculum in real-world examples, using prior knowledge on which to seat new knowledge, and attempting to make the learning experience enjoyable by presenting the material in a game-like environment. The hands-on nature of *Stat Lady* was believed to render abstract probability concepts concrete. Differences between, for example, hearing about dice-rolling experiments from a lecture, and actually having *Stat Lady* (or the learner) roll the dice herself (as many times as necessary to get the point) reflect the difference between passive and active learning, the empirical question underlying the first experiment.

Experiment 1 globally compared the influence of learner ACTIVITY on learning outcome (i.e., *Stat Lady* -- active vs. Lecture -- passive). The main finding was that both treatment conditions showed large increases from pre- to posttest (after just 3 hr instruction), but there was no main effect of condition on outcome. We viewed this as very promising because learners assigned to *Stat Lady* managed to perform as well on the outcome test as the Lecture group, despite the presence of many factors strongly favoring the Lecture condition: (1) Lectures constitute much more familiar learning environments for Ss than computer-administered instruction; (2) The professor delivering the lecture was both popular and had over 20 years experience teaching the subject matter, while *Stat Lady* was on her "first teaching assignment;" (3) Subjects in the Lecture group were mistakenly informed about the posttest, thus had the opportunity to study for it, while no other Ss knew about it; (4) The Lecture group had a significantly higher pretest score for procedural test items than the other groups (probably due to their having, by chance, higher quantitative SAT scores, compared to the other groups, implying an incoming math advantage); and (5) Subjects in the Lecture condition were exposed to all curricular elements during the three one-hour classes, but not all Ss in the *Stat Lady* group were able to complete each of the one-hour curriculum units in the designated time. Thus, *Stat Lady* Ss, with lower pretest scores, not only learned to navigate within a novel learning environment, they learned as much of the subject matter as the Lecture group.

Experiment 2 examined the computer's contribution to learning by holding learner activity constant, and varying the instructional medium (computer vs. workbook -- both experiential environments). Findings revealed no differences on any outcome measure between the two conditions. Nor were any interactions found relating aptitudes or knowledge type to learning outcome. Some of the same discussion, above, may be applied to Experiment 2 results. That is, we were encouraged to see that *Stat Lady* learners performed the same on the outcome tests compared to those individuals learning from the more familiar Workbook condition. We were surprised, however, that *Stat Lady's* bells & whistles did not appear to enhance learning (i.e., the computer delivered instruction in color, with animation, sound effects, and immediate feedback, while the workbooks presented black and white information, with static pictures, no sound, and slightly delayed feedback). In short, the computer appeared to contribute nothing to learning outcome.

The last analysis looked at group differences in terms of attitudes toward the learning experience. In Experiment 1, there was no difference between conditions on this variable -- Ss in the Lecture and *Stat Lady* conditions reported a similar degree of positive attitude. However, one group's "positive" was the other group's "negative" (i.e., people in the Lecture condition disliked the "boring" format, but appreciated the ability to ask the professor "why" questions. In contrast, *Stat Lady* Ss really enjoyed the stimulating environment, but were unable to explicitly ask "why" kinds of questions). So, the positives and negatives tended to balance out between groups. In Experiment 2, *Stat Lady* Ss reported a significantly greater ENJOYMENT of their learning experience compared to those in the Workbook condition, and also felt that instructions were clearer, and help more beneficial if delivered from a computer than workbook (although they were actually the same). In summary, *Stat Lady* and Lecture Ss were equally positive -- each condition had its strengths and weaknesses. Workbooks, on the other hand, were judged more negatively -- not only were they less enjoyable, one could not ask "why."

The results of the present experiments allow for some tentative conclusions. First, it appears that *Stat Lady* (compared to a lecture) is clearly the best environment for high aptitude Ss. Furthermore, low aptitude Ss also show a slight *Stat Lady* advantage, although these subjects may require more of a mixture of computer and lecture to optimize learning. When we analyzed the data with outcome type in the equation (declarative vs. procedural items), we found a significant and interesting interaction between condition and knowledge type, implying that it may be efficacious to use *Stat Lady* to instruct certain parts of the curriculum (e.g., declarative knowledge) and the lecture method to instruct other parts. These findings, taken together, suggest that some combination of computer and lecture may be optimal to enhance learning outcome as well as increase enjoyment of the learning experience.

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