AC 2008-1060: SYNOPSIS LABORATORY REPORTS: EFFECTS ON STUDENT LEARNING AND CURRICULAR BENEFITS

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Synopsis Laboratory Reports:
Effects on Student Learning and Curricular Benefits

Introduction

This study examined the effect on student learning of writing laboratory (lab) reports in the synopsis format versus the traditional format of the field of industrial technology, as well as the benefits of reduced instructor grading time and reduced student writing time. The synopsis lab report format, if able to provide students with an equally effective learning experience as the traditional lab report format while requiring less of an instructor's time for grading and freeing up a significant amount of students' out-of-class study time for other assignments, would be beneficial to instructors who choose to adopt it and to their students.

Laboratory Reports in Industrial Technology

Many industrial technology programs incorporate both a lecture component and a laboratory component in order to help students increase their understanding of the curriculum. Felder and Peretti[9] stated that "a basic tenet of learning theory is that people learn by doing, not by watching and listening. Industrial technology accreditation requirements emphasize the importance of laboratory experiences.[18] While some researchers[11,22,6] question the value of lab experiments, there is no doubt that the lab experiment is a commonly employed teaching tool in industrial technology. The purpose of laboratory experiments in industrial technology is, as Gillet, Latchman, Salzmann, and Crisalle[10] said, "…to motivate, illustrate, and enlighten the presentation of the subject matter addressed in the lecture" (p. 190).

A written report often follows the lab experiment in order to cause the student to reflect on, summarize, and quantify the laboratory experience. To learn by doing in the laboratory, followed by reflecting on that experience and writing about it in the form of a report, can only further enhance learning. Lederman[16] stated that "the assumption that students are likely to learn the nature of science through implicit instruction (i.e. performance of scientific inquiry with no reflection on the nature of the activity) should be called into question" (p. 928). A well-designed lab report asks a student to reflect on the activity, the assigned readings, and the lecture content, and synthesize these into a new, succinct document. These are the primary goals of the synopsis lab report format.

Traditional Laboratory Reports

The traditional lab report, for the purposes of this study, was defined as a report in which subjects may take as much space as they wish in order to report the information in Table 1. The traditional style of lab report is written chronologically, similar to other documents that have the purpose of reporting work. Students present the reason for the work in an introduction (the *before*), detail this work in a body (the *during*), and report its outcome in a conclusion (the *after*).[8] For the purposes of this study, subjects were required to separate the conclusion into two separate sections: the *discussion* and the *conclusion*. The discussion section was the place to discuss the experiment, the procedure, and the results, while the conclusion was a brief section that attempted to tie the experiment to the curricular content.

While the experiment itself may be on the third (*application*) level of Bloom's *Taxonomy of Educational Outcomes*[3], the traditional lab report style promotes the reiteration of the experimental procedure and results and does not seem to encourage deep thought regarding the purpose of the experiment and its relation to the curriculum. Even though it was required in the paper guidelines, students rarely provided more than a few sentences of shallow critique; therefore, the writer of a traditional lab report operates at the second level (*comprehension*). At the comprehension level, students demonstrate their understanding of concepts by recalling what they have learned, translating and interpreting findings, and explaining expected and unexpected results[3,15].

Table 1

Major Headings Required for Traditional Laboratory Reports.

Heading	Description
Title Page	A specific format was specified.
Introduction	The student was to explain why the experiment was worth performing, what the intended outcomes were believed to be, and the perceived importance of the experiment. This section was to be written in future tense.
Results	The student was to include the completed lab experiment handout as the results section. The results were graded for accuracy.
Discussion	The setup, procedures employed, measurements and results, and problems encountered with equipment or procedures of the lab experiment were to be discussed in detail in this section. This section was to be written in past tense.
Conclusion	The student was to conclude by summarizing the experiment and making an attempt to relate the lecture and reading to the lab. This section was to be written in the present tense.

Synopsis Laboratory Reports

A synopsis report was restricted to a single page and focused on relating the content of the experiment to the curricular content. For example, if an experiment was performed on the electrical quantity of resistance, a synopsis should not have reported the results of any measurements taken during the experiment, but instead generically discussed the electrical property of resistance. The report was to be written in a style similar to an abstract or executive summary; it was to be written to an audience that wants to know the gist of the work that was performed, sparing the minutiae – a corporate Vice President, for example. The writer was not permitted to discuss experiment-specific material such as setup, procedures, or measurement results, and it was to be written in the passive voice and present tense.

The synopsis format ignores the *before* and *during*, focusing on the *after*, or conclusion[8]. A synopsis was to be written devoid of all experiment-specific information and facts (such as problems encountered, measured results, and procedures) and required the writer to think deeply about the purpose of the experiment as it related to the theoretical concept(s) discussed in assigned readings and lecture content, and to synthesize these into a new, succinct document. While interpretations of Bloom's Taxonomy vary[3,15], the recombination and summarization of readings, class discussions, and laboratory experiences to produce an original work seems descriptive of the *synthesis* level of the taxonomy.

Writing Across the Curriculum

Writing Across the Curriculum (WAC)[4], a concept established in the 1980s in response to the perception that students were lacking in writing skills, recognizes "the importance of writing in a non-English curriculum and encourages college teachers to include discipline-specific writing in their courses" (p. 409). WAC activities in the classroom can be categorized as Writing to Learn (WTL) or Writing in the Disciplines (WID). WTL is summarized by Romberger[20] as:

> [an] *approach to WAC* [that] *frequently makes use of journals, logs, microthemes, and other, primarily informal, writing assignments. If they* [students] *write reactions in their own words to information received in class or from reading, students often comprehend and retain information better. Also, because students write more frequently, they either maintain or improve their writing skills and avoid a decrease in writing ability from entrance to senior.*

On the other hand, WID[5] "is premised on the idea that students become better readers, thinkers, and learners in a discipline by [writing in] the forms and conventions specific to it" (p. 19). A WID-focused course might include article and book reviews, annotated bibliographies, literature reviews, research papers, and/or laboratory reports as assignments. The synopsis lab report is one method of bringing this type of writing into the curriculum and falls into the *Writing in the Disciplines* concept of the *Writing Across the Curriculum* movement[5,20].

Rationale for the Study

Goal of the Study

The goal of this study was to determine if the synopsis lab report format is at least as effective a learning tool as the traditional lab report format, while requiring less time for students to prepare and for instructors to grade. As long as the synopsis format does not impact student learning negatively, the benefits of reduced student writing time and instructor grading time provide justification for its adoption in curricula which rely on a laboratory component.

Purposes of the Study

The study had four purposes:

1. To determine if the synopsis lab report format is at least as effective as a learning tool as the traditional lab report format in terms of both exam grades and lab report grades.
2. To determine the difference in instructor grading time.
3. To determine the difference in student writing time.

4. To contribute useful information regarding lab report requirements to the field of industrial technology, to other disciplines which incorporate laboratory experiments as a part of their curricula, and to society in general.

Need for the Study

The literature repeatedly reflects industry's desire for graduates who have solid written communication skills. Some examples:

- Nixon and Fischer[19] found that

  > [a] lengthy review of the curriculum in the College of Engineering at the University of Iowa, conducted from 1997 to 2000 made it apparent that subjects were not gaining appropriate communications skills from the curriculum. It was apparent from both advisory board input and from ABET [Accreditation Board for Engineering and Technology] concerns that steps were needed to address this lack (p. T2G/1).

- Doumont[7] said that "it was a well-known complaint from real-world companies that the young graduates they hire were ill-prepared for… communicating in the workplace" (p. 138).
- Baren and Watson[2] also found a strong desire for engineering graduates with good communication skills (accreditation guidelines indicate the same desires for industrial technology students[18]):

  > [A] cursory look through the classified section of any newspaper indicates that 'good communication skills' were a requirement of most companies which hire engineers. Campus recruiters, members of [Temple University's] industrial advisory committees, senior design industry advisors and other practicing engineers continue to emphasize the need for young engineers 'who can communicate' (p. 432).

Many authors[13,17,25] have alluded to instructors' desires to minimize the amount of time spent grading, which is surely a point few instructors responsible for grading papers would argue. An exhaustive review of the literature has not yielded evidence that research on the synopsis method has been conducted, further demonstrating the need for this study.

Research Questions

The study was guided by five research questions:

1. Does the style of lab report influence student learning based on comprehensive exam scores?
2. Does the style of lab report influence mean scores on lab experiments?
3. Does the style of lab report influence individual student scores on individual lab experiments?
4. How great is the difference in the time required for instructors to grade the two types of lab reports?
5. How great is the difference in the time required for student preparation of the two types of lab reports?

Methodology

Population and Sample

The population of this study was undergraduate industrial technology majors at Iowa State University. The convenience sample contained the students who enrolled in ITEC 140, Electrical Fundamentals, in the Fall 2004 (30 students) and Spring 2005 (26 students) semesters, for a total sample size of 56 students. Each student was counted as one experimental unit. Each subject was randomized into one of two groups: Group 1 wrote five synopsis reports followed by four traditional reports; Group 2 wrote five traditional reports followed by four synopsis reports.

Data Collection

Each subject was required to perform nine lab experiments, which were designed to support and enhance the learning of the course content. After each experiment, subjects were allotted one week in which to complete and submit a report based on that experiment. The instruments used for data collection included a series of nine lab reports from each subject (five synopses and four traditional reports or vice versa), two exams, composite American College Testing (ACT)[1] college placement scores, and an end of semester "exit survey" of attitudes and preferences concerning the two report formats administered via *WebCT Campus Edition* version 4.1[24].

Assumptions

1. The participants worked to the best of their abilities on all lab experiments and lab reports.
2. The participants were representative of undergraduate industrial technology students at Iowa State University.
3. Concerns about engineering students' written communication skills closely parallel those of students in industrial technology.
4. An abbreviated lab report format that provides students with an equivalent learning experience concerning the technology content is desirable to both educators and students in the field of industrial technology.
5. Instructors desire to decrease the amount of time spent on grading assignments.

Limitations

1. The results of the exit survey, like any survey, could be influenced by student bias; perhaps some students selected their responses based on what they thought the instructor wanted to hear. The potential impact of this bias was reduced by offering no incentive for students to respond in a certain way (including grading incentives), by making survey participation and responses anonymous and voluntary, and by prefacing the survey with a statement that continuous improvement of laboratory instruction requires honest responses.
2. The times reported by students on their lab reports were assumed to be accurate.
3. The study had a relatively small sample size (n = 56).

Delimitations

1. Only subjects who enrolled in the Fall, 2004 and Spring, 2005 semesters of ITEC 140, Electrical Fundamentals, were invited to participate in the study.
2. Data regarding subjects' individual learning styles were neither gathered nor taken into account in the analysis.

Grading and Reliability

Traditional reports were graded on content, clarity, completeness, spelling, grammar, correctness of results, and adherence to format. Synopsis reports were graded on content, clarity, completeness, spelling, adherence to format, and grammar, but the results of the lab were not considered as a part of the grade. Instead, students who wrote synopsis reports had their experimental results checked for accuracy in the lab and were given instructor approval to consider the experiment completed and begin writing their reports. The purpose of this check was to ensure correct application of the experimental methods and data analysis. This formal check required no additional time of the instructor; merely initials to indicate that the work was scrutinized by the instructor (students from both groups were able to benefit from this type of interaction). Each report was worth a maximum of 10 points.

The use of grading rubrics provided reliability by ensuring that every lab report with a similar grade represented a comparable level of achievement. The course materials (lecture content, textbook, homework assignments, lab experiments, exam content, and other handouts), as well as the course structure (rules, expectations and requirements, and weighting of graded materials) remained fixed for the duration of the study.

To control bias (positive or negative), every synopsis was graded anonymously by requiring the subjects to format their reports with their name in the upper header – when the reports were clipped into a clipboard for grading, the clip covered the names of the authors. Traditional reports, which had a cover page as a requirement of the format and the lab handout included as the results section, were not assessed anonymously.

Statistical Design

The statistical analyses were performed at the $\alpha = 0.05$ level using *SPSS for Windows* version 11.0 (2001)[23] or *JMP* version 5.1.2 (2005)[21] statistical software packages.

Research Question 1: Does the style of lab report influence student learning based on comprehensive exam scores?

To determine if students who wrote synopsis reports learned the content (as measured by comprehensive exam scores) as well as the students who wrote traditional reports, the Latin Square Design, two-sample *t*-tests (equal variances not assumed), and regression analyses were employed. The two-sample *t*-test was applied to each exam to discover if there was a statistically significant difference in the mean scores between subjects who wrote synopses and subjects who wrote traditional reports on either exam. The Latin Square Design was used to examine the main effects of the two *treatments*, (synopsis or traditional), the *order* in which the treatments were administered (synopsis first or traditional first), and the two *exams*, as well as the effects of the covariates *ACT score* and the *ACT score * (main effect)* interactions. Regression analyses were employed to discover how any significant effects of the *ACT score* covariates affected the students' learning outcomes. The Chi-squared Test of Independence was employed to discover any significant differences between positive and negative responses on the exit survey.

Research Question 2: Does the style of lab report influence mean scores on lab experiments?

The two-sample *t*-test (equal variances not assumed), paired-samples *t*-test, regression analysis, and Analysis of Covariance were used to discover whether the style of lab report influenced students' ability to successfully complete the lab assignment as measured by mean scores on lab experiments. The main effect of the *order* in which subjects wrote the two styles of lab reports was analyzed with the two-sample *t*-test to discover if there was a significant difference in mean report scores between subjects who wrote synopsis reports first (Group 1) and subjects who wrote traditional reports first (Group 2). The paired-samples *t*-test was applied to the mean scores of the two report types to discover if the main effect of *treatment* (the two report types) was statistically significant. The difference of each subject's mean synopsis report and traditional report scores was computed and analyzed with the two-sample *t*-test to discover whether there was a significant interaction effect (*treatment * order*). Analysis of Covariance was employed, using the overall mean lab report scores and the difference between each student's mean lab report scores for each treatment as dependent variables and ACT scores as the covariate.

Research Question 3: Does the style of lab report influence individual student scores on individual lab experiments?

To discover whether the type of lab report influenced individual students' scores on the nine individual lab experiments, the mean synopsis grade and the mean traditional report grade for each of the nine lab experiments were analyzed with the two-sample *t*-test (equal variances not assumed).

Research Question 4: How great is the difference in the time required for instructors to grade the two types of lab reports?

To discover the differences in mean grading time between synopsis and traditional reports, the paired samples *t*-test was employed.

Research Question 5: How great is the difference in the time required for students to write the two types of lab reports?

To discover the differences in mean writing time between synopsis and traditional reports, the paired samples *t*-test was employed.

Results

The raw data collected for this study can be found in Appendix A.

Research Question 1

The statistical analyses of exam scores revealed that students who were required to write their laboratory reports in the synopsis format learned the curriculum (as represented by comprehensive exam scores) as well as those who wrote their reports in the traditional format.

- The type of report had no negative impact on student learning ($p = 0.932$).
- The order in which students wrote the two report types had no effect on learning ($p = 0.6628$).
- Students performed similarly on the two exams ($p = 0.4789$).

These results indicate that synopsis lab reports would have no negative impact on the learning of industrial technology students if implemented elsewhere in the curriculum.

A sample of the output of the statistical analysis used to answer this research question can be found in Appendix B. This is provided as an example of the type of statistical analysis used in this study. For the complete analysis of the data, see Hoffa.[12]

Research Question 2

The statistical analyses of mean lab report scores revealed that the synopsis lab report format had no negative influence on student learning in terms of mean lab experiment scores.

- There was no difference in student learning between students who wrote synopsis reports and students who wrote traditional reports ($p = 0.843$).
- The order in which students wrote the two report types had no significant effect on learning ($p = 0.427$).
- There was not a significant interaction effect between the type of report and the order in which the two types of reports were written ($p = 0.871$).

The lab report mean score analyses strongly indicate that, in terms of lab report grades, the students in the sample who wrote their lab reports in the synopsis format learned the material just as well as those who wrote their lab reports in the traditional format. Therefore, one can assume that synopsis lab reports would have no negative impact on the learning of laboratory content (as measured by the scores of lab reports) for industrial technology students if implemented elsewhere in the curriculum.

Research Question 3

The report type was found to have no impact on student learning (in terms of mean lab report scores) on the majority of individual lab assignments (7 of 9). However, the statistical analyses of individual lab report grades did reveal a difference in experiments 1 and 4 (*Lab 1:* $p = 0.018$; *Lab 4:* $p < 0.001$). In the first assignment, when students were most unfamiliar with the synopsis report format, there was a slight advantage to using the traditional format. In the fourth assignment, students performed better using the synopsis format. To fully understand the significant differences between groups on these two experiments, additional study is required.

Research Question 4

The paired-samples *t*-test analysis of the difference in grading time between synopsis reports and traditional reports has revealed that the synopsis report format requires between four and six fewer minutes per report to grade ($p < 0.001$). If a course requires 10 lab reports from each of 25 students, its instructor could expect (with 95% confidence) to spend between 1,115 and 1,440 fewer minutes (between approximately 18 and 24 fewer hours) grading those papers if the synopsis format were used instead of the traditional format. This represents a significant reduction in workload for course instructors (and/or teaching assistants responsible for grading papers), which becomes increasingly significant with class size. This reduction in grading workload could be used by busy professors to increase productivity in research, service, or improving other aspects of teaching, providing a better learning environment for the students.

Research Question 5

The paired-samples *t*-test analysis of the difference in mean writing time between synopsis reports and traditional reports has revealed that students require between 32 and 44 fewer minutes per report to write in the synopsis format than in the traditional format ($p < 0.001$). If a course instructor requires each student to write 10 lab reports, each student could be expected to spend between 324 and 444 fewer out-of-class minutes (between five and seven hours) writing synopsis lab reports than traditional lab reports over the duration of the semester. If the results of the writing time analyses are scrutinized strictly in terms of the effect of time on task, one could conclude that increasing the mean amount of out-of-class writing per curriculum unit from 51 minutes to 89 minutes per student had no effect on how well students performed on exams or assignments.

Summary of Exit Survey Results

The analysis of the exit survey with chi-squared tests of independence revealed that the students:

- preferred the synopsis format to the traditional format ($p < 0.001$);
- perceived that the synopsis format allowed them to score higher on their exams ($p = 0.039$), even though the exam score data analyses do not support this finding;
- perceived that the synopsis format required them to learn the material at a deeper level (the grader would concur; however, further examination using some criteria such as Bloom's Taxonomy is necessary to determine the actual differences in the level of student learning);
- believed the synopsis report format helped them achieve higher grades on their lab reports, even though the analyses of lab report scores do not support this finding ($p = 0.002$);
- recognized the reduced time to write synopsis reports ($p < 0.001$); and
- perceived that they had improved their technical writing skills by writing both types of lab reports (not statistically analyzed).

Conclusions

Based on the results of these studies, the following conclusions have been reached:

- The synopsis lab report format does not negatively impact student learning [no difference in exam scores ($p = 0.932$) or in lab report scores ($p = 0.843$)].
- Synopsis lab reports reduces student writing time by between 32 to 44 minutes, allowing for additional assignments.
- Synopsis lab reports require four to six fewer minutes for instructors to grade than traditional reports.

Recommendations for Future Research

Based on the findings of these studies, recommendations for future research studies include:

- Repeat this study to verify or refute these findings by using synopsis lab reports in other content areas and curricula (e.g. engineering); at other universities; and with a larger sample size to increase the power of the statistical analyses and reduce the spread of the confidence intervals.
- Investigate whether the synopsis lab report format encourages students to develop abilities at higher levels of Bloom's Taxonomy than the traditional format. Hypothetically, the synopsis format requires readers to work at the synthesis level and the traditional format requires students to work at the application level.
- Gather data on students' learning styles using a tool such as the Kolb Learning Style Inventory[14] and investigate relationships between learning styles and the lab report formats, which will establish whether learning styles influence student success on synopsis or traditional reports.
- Investigate the effects of demographic factors such as age, student socio-economic status, first-generation/traditional, underclassman/upperclassman, gender, race, etc., on success with the synopsis format.

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Appendix A – Raw Data

Research Data Set - Fall 2004

	ID	Lab 1	grade time	write time	Lab 2	grade time	write time	Lab 3	grade time	write time	Lab 4	grade time	write time	Lab 5	grade time	write time	Lab 6	grade time	write time	Lab 7	grade time	write time	Lab 8	grade time	write time	Lab 9	grade time	write time	Lab Avg	Exam 1	Exam 2
Group A	1	6	7	30	8	5	40	6	7	30	9	6	30	7	9	25	7	10	50	8	9	65	7.5	9	50	9	7	50	188	31	35
	2	8	6	40	10	4	45	9	4	30	10	2	30	9	4	30	9.5	13	75	9	8	75	10	5	70	8.5	6	75	210	39	41
	3	6	6	60	9.5	3	60	9	3	45	9	5	60	9	4	60	8.5	8	120	9	6	100	9	7	90	9.5	5	70	286	41	40
	4	5	9	120	5	6	120	3	8	120	5	4	100	6	4	80	7	12	240	7.5	9	280	7.5	7	120	7	6	120	517	24	29
	5	7	9	68	9	6	75	8.5	5	80	9.5	3	110	8.5	3	90	8.5	10	151	9.5	10	170	8.5	8	140	9.5	9	150	407	41	33
	6	7	7	42	7.5	5	48	6	6	83	8	5	44	7	8	82	9	14	280	9	9	234	9	8	100	8.5	6	104	418	40	39
	7	7	5	57	9	4	105	7	7	47	8.5	3	72	8	4	63	8.5	11	139	9	8	127	8.5	6	73	8.5	6	75	322	38	42
	8	7	8	30	7	5	40	7	7	50	8	5	47	7	5	42	9	10	102	9	7	106	8	7	102	8	6	44	257	26	36
	9	7	8	65	9	7	80	8	7	85	10	2	75	8	5	82	8.5	7	130	9.5	5	135	9	7	120	8.5	7	126	359	32	31
	10	7	5	45	8	4	55	7	6	60	7	4	47	7	5	55	7.5	13	95	8.5	6	55	7.5	7	65	6	3	55	237	30	27
	11	6.5	6	57	7	3	33	7	3	54	8	3	58	6	4	70	0	0	0	8	7	120	8	7	41	7.5	5	55	210	39	34
	12	7.5	8	60	9.5	4	65	8.5	5	65	8	4	45	8.5	5	75	7	14	100	9	6	120	9	7	65	9	6	75	290	41	41
	13	7	8	83	9	8	72	7	6	84	8	6	77	8	4	63	9.5	12	136	10	8	106	9	9	92	10	7	92	341	32	30
	14	6	7	95	6	7	220	7.5	3	220	8	4	250	6	6	330	9	8	220	7	6	220	6	7	200	6	6	200	746	18	19
	15	8	5	55	8.5	6	42	7.5	5	32	9.5	4	37	6.5	5	28	9	9	105	8.5	5	48	8	6	77	9.5	6	105	218	46	30
Group B	16	6	9	105	10	9	44	8	7	96	7	8	66	9	7	100	9.5	2	38	7	5	58	0	2	58	0	2	86	268	37	26
	17	7	8	46	7	5	103	10	8	59	7.5	10	91	8.5	6	112	9	4	55	8	5	67	9	3	34	9.5	2	42	277	40	34
	18	7	6	45	9	10	50	9.5	11	54	7.5	15		7.5	16	65	8.5	6	35	9.5	4	35	10	2	28	9.5	3	23	192	43	43
	19	6	15	120	6	7	64	5	15	75	6.5	10	60	8	11	64	7	3	47	0	8		0	2	55	6	2	55	250	17	27
	20	7	11	90	7	11	120	8.5	10	90	6	8	90	6.5	14	110	8.5	3	80	7	3	60	8	3	60	8	2	60	332	42	30
	21	7	14	185	8.5	10	189	7.5	11	189	7.5	7	213	0	0	0	7	6	104	6	3	62	0	0	0	7	3	143	417	33	30
	22	8	11	84	9.5	10	135	8.5	13	104	8	15	145	9.5	15	193	9	3	55	9.5	4	48	10	3	48	9.5	2	44	387	42	35
	23	7	11	90	8.5	10	90	9	9	90	8	11	60	0	0	0	9	3	45	7.5	4	50	6.5	2	45	9	1	35	234	30	40
	24	8	10	36	9.5	8	63	9.5	7	56	8.5	8	54	8.5	8	53	7	3	34	9	4	42	9	2	32	9	2	36	199	39	38
	25	9	12	210	10	8	195	9.5	11	225	9.5	10	195	9.5	14	240	9.5	3	53	8	3	50	9	3	48	10	2	52	546	37	41
	26	4	8	53	9	7	78	5	13	55	6.5	8	66	8	8	105	9	4	33	7.5	4	35	9	2	39	9	2	44	234	25	31
	27	6	17	58	7.5	12	72	9	12	83	8	17	71	7	10	61	8	3	44	7	5	38	7.5	3	37	9.5	2	39	245	38	27
	28	3	8	37	8	9	52	8.5	13	52	6.5	14	55	8	9	65	8.5	5	32	7.5	3	31	8	3	35	9	2	34	196	47	38
	29	4	8	45	8	10	125	7.5	10	115	8	12	74	9	10	144	10	3	83	7.5	4	45	6	2	65	7	3	54	329	34	36
	30	8.5	14	135	9.5	12	155	9	12	110	9.5	10	91	9.5	15	135	9.5	3	37	9.5	3	37	7.5	4	41	9	3	54	358	42	41

Appendix A – Raw Data (continued)

Research Data Set - Spring 2005

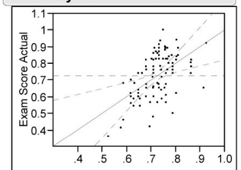
	ID	Lab 1	grade time	write time	Lab 2	grade time	write time	Lab 3	grade time	write time	Lab 4	grade time	write time	Lab 5	grade time	write time	Lab 6	grade time	write time	Lab 7	grade time	write time	Lab 8	grade time	write time	Lab 9	grade time	write time	Lab Avg	Exam 1	Exam 2
Group A	16	8.5	4	32	8	2	27	7.5	3	26	8.5	4	45	8.5	4	30	8.5	6	51	7	11	51	8	11	51	7.5	9	51	181	37	30
	17	8.5	4	26	7	4	46	9	4	37	9.5	7	29	9.5	4	43	8	8	98	9	8	84	9	10	55	10	5	68	219	44	43
	18	7.5	4	35	8.5	3	55	8	3	63	9	3	72	9	3	95	8	8	120	9	11	140	8.5	8	115	7.5	8	95	325	43	39
	19	6.5	4	45	9	3	60	9	2	55	9	3	90	9.5	4	110	5	15	90	7	17	150	7	14	135	8.5	7	150	347	34	27
	20	8	3	54	9	4	61	8.5	3	75	9	3	48	8.5	3	63	8.5	6	72	8	13	110	8.5	13	94	9	13	89	281	31	30
	21	7.5	3	33	9	2	68	8.5	3	43	8	3	41	9	2	42	9.5	7	83	9.5	9	74	0	0	0	8	9	64	193	41	38
	22	8.5	4	30	9	2	30	7	4	30	8.5	4	30	7.5	4	30	8.5	13	90	0	0	0	0	0	0	8	9	90	131	41	37
	23	7	5	55	8.5	4	50	7	4	50	8.5	3	49	8	3	45	7.5	7	102	7	9	100	7.5	9	90	8	6	60	262	23	25
	24	7	3	32	8	2	35	8	4	33	8.5	5	27	9	4	51	6	7	76	7	8	78	7	10	78	8	9	78	209	41	33
	25	7	4	70	8.5	3	55	8	4	60	8.5	6	50	8	4	65	8.5	7	100	8.5	8	95	7.5	12	75	8.5	10	70	276	33	40
	26	6	3	46	8.5	4	42	3	5	38	9	4	48	7	3	53	8	10	80	7.5	12	105	8	11	105	9.5	11	50	254	38	41
	27	8.5	5	34	8.5	2	28	7.5	4	30	7.5	4	38	8.5	4	41	9	7	72	7	10	75	7.5	15	80	8	13	74	208	31	39
	28	9	3	45	8.5	4	37	8.5	3	75	9	4	82	8.5	3	73	8.5	7	124	8.5	15	105	9	11	75	9.5	8	95	298	35	27
	29	5	5	43	7.5	5	38	6.5	6	42	8	4	38	6.5	4	41	7	11	144	6.5	9	73	6.5	9	62	6.5	8	78	238	28	25
Group B	45	9.5	5	57	9	10	42	7.5	10	69	7	11	72	7.5	9	94	8	2	86	8	4	120	7.5	5	120	7	5	120	315	35	26
	46	8	7	80	7	11	67	6	10	67	5	9	45	0	0	0	6.5	2	23	8.5	5	45	9	4	32	8.5	4	30	186	44	38
	47	8	7	0	7	8	65	7	8	35	7	9	40	6	9	45	8.5	4	46	8	4	52	9.5	3	50	7	4	36	181	30	31
	48	9	7	114	7.5	14	92	5	9	78	8	12	46	8	13	151	8	3	71	7.5	4	62	7	4	48	8	3	55	318	39	28
	49	9.5	9	130	8	9	145	8.5	8	120	8	9	115	8.5	15	130	8	3	45	7	4	50	7	4	30	7.5	3	35	359	30	22
	50	8.5	10	120	7	12	120	7	11	150	6	11	120	8.5	10	150	7	5	90	8	5	95	6.5	4	70	8.5	4	65	420	21	26
	51	10	6	150	9.5	6	130	10	6	120	9.5	7	130	10	11	130	10	2	45	9.5	2	45	10	2	45	10	2	45	370	45	46
	52	7.5	7	72	7	11	83	9	7	64	8.5	10	57	9	8	54	7.5	4	36	8.5	5	39	8	5	34	6	2	38	227	38	38
	53	10	7	95	9.5	7	83	6	6	55	9	7	92	9	10	74	7.5	5	41	9.5	2	49	9	3	55	6	4	51	267	32	33
	54	7	9	120	7	9	140	6.5	9	140	6	11	140	7	8	140	5	4	40	6	6	40	7.5	5	140	7	3	135	408	31	26
	55	9	6	104	7	10	96	5	7	110	7.5	10	102	8	16	115	9	2	55	7	5	55	7	5	50	8	4	52	326	37	30
	56	7	7	94	7	9	105	6	9	108	8	12	121	8.5	11	128	7	4	46	9	3	51	8	5	50	8.5	6	55	333	34	38

Appendix B – Sample Statistical Analysis for Research Question 1

Response Exam Score

Whole Model

Actual by Predicted Plot



Exam Score Predicted P<.0001
RSq=0.29 RMSE=0.1172

Summary of Fit

RSquare	0.290248
RSquare Adj	0.232477
Root Mean Square Error	0.117246
Mean of Response	0.725726
Observations (or Sum Wgts)	94

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	7	0.4834552	0.069065	5.0241
Error	86	1.1822089	0.013747	Prob > F
C. Total	93	1.6656641		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	40	0.8272709	0.020682	2.6804
Pure Error	46	0.3549380	0.007716	Prob > F
Total Error	86	1.1822089		0.0007
				Max RSq
				0.7869

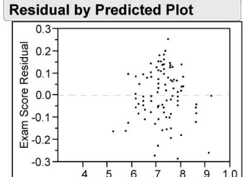
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.2906365	0.080157	3.63	0.0005
Treatment[1]	-0.00106	0.012388	-0.09	0.9320
Order[1]	0.0054212	0.012388	0.44	0.6628
Exam[1]	-0.008809	0.012388	-0.71	0.4789
ACT	0.0195545	0.003531	5.54	<.0001
(ACT-22.5957)*Treatment[1]	-0.001239	0.003531	-0.35	0.7266
(ACT-22.5957)*Order[1]	0.0088184	0.003531	2.50	0.0144
(ACT-22.5957)*Exam[1]	0.0036431	0.003531	1.03	0.3051

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Treatment	1	1	0.00010069	0.0073	0.9320
Order	1	1	0.00263274	0.1915	0.6628
Exam	1	1	0.00695200	0.5057	0.4789
ACT	1	1	0.42153978	30.6650	<.0001
ACT*Treatment	1	1	0.00169108	0.1230	0.7266
ACT*Order	1	1	0.08572786	6.2363	0.0144
ACT*Exam	1	1	0.01463162	1.0644	0.3051

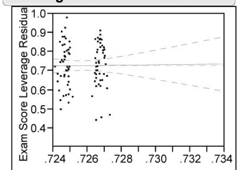
Residual by Predicted Plot



Exam Score Predicted

Treatment

Leverage Plot



Treatment Leverage, P=0.9320

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
1	0.73142407	0.01751873	0.722109
2	0.73354440	0.01751873	0.729343

LSMeans Differences Student's t

Alpha= 0.050 t= 1.98793

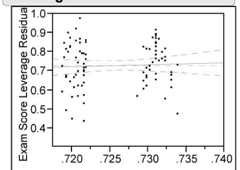
LSMean[i]	Mean[i]-Mean[j] / Std Err Dif / Lower CL Dif / Upper CL Dif	LSMean[j] 1	LSMean[j] 2
1	Mean[i]-Mean[j]	0	-0.0021
	Std Err Dif	0	0.02478
	Lower CL Dif	0	-0.0514
	Upper CL Dif	0	0.04713
2	Mean[i]-Mean[j]	0.00212	0
	Std Err Dif	0.02478	0
	Lower CL Dif	-0.0471	0
	Upper CL Dif	0.05137	0

Level		Least Sq Mean
2	A	0.73354440
1	A	0.73142407

Levels not connected by same letter are significantly different

Order

Leverage Plot



Order Leverage, P=0.6628

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
1	0.73790541	0.01779313	0.716068
2	0.72706305	0.01723995	0.734982

LSMeans Differences Student's t

Alpha= 0.050 t= 1.98793

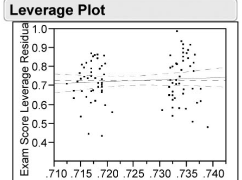
LSMean[i]	Mean[i]-Mean[j] / Std Err Dif / Lower CL Dif / Upper CL Dif	LSMean[j] 1	LSMean[j] 2
1	Mean[i]-Mean[j]	0	0.01084
	Std Err Dif	0	0.02478
	Lower CL Dif	0	-0.0384
	Upper CL Dif	0	0.06009
2	Mean[i]-Mean[j]	-0.0108	0
	Std Err Dif	0.02478	0
	Lower CL Dif	-0.0601	0
	Upper CL Dif	0.03841	0

Level		Least Sq Mean
1	A	0.73790541
2	A	0.72706305

Levels not connected by same letter are significantly different

Exam

Leverage Plot



Exam Leverage, P=0.4789

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
1	0.72367487	0.01751873	0.717872
2	0.74129360	0.01751873	0.733580

LSMeans Differences Student's t

Alpha= 0.050 t= 1.98793

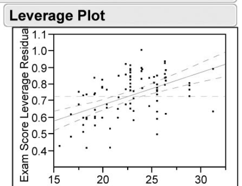
LSMean[i]	Mean[i]-Mean[j] / Std Err Dif / Lower CL Dif / Upper CL Dif	LSMean[j] 1	LSMean[j] 2
1	Mean[i]-Mean[j]	0	-0.0176
	Std Err Dif	0	0.02478
	Lower CL Dif	0	-0.0669
	Upper CL Dif	0	0.03163
2	Mean[i]-Mean[j]	0.01762	0
	Std Err Dif	0.02478	0
	Lower CL Dif	-0.0316	0
	Upper CL Dif	0.06687	0

Level		Least Sq Mean
2	A	0.74129360
1	A	0.72367487

Levels not connected by same letter are significantly different

ACT

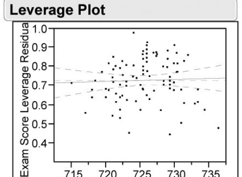
Leverage Plot



ACT Leverage, P<.0001

ACT*Treatment

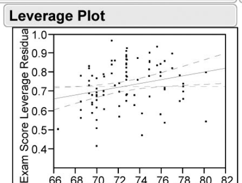
Leverage Plot



ACT*Treatment Leverage,
P=0.7266

ACT*Order

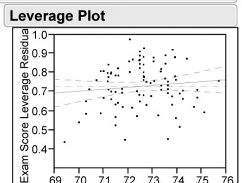
Leverage Plot



ACT*Order Leverage, P=0.0144

ACT*Exam

Leverage Plot

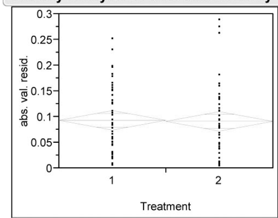


ACT*Exam Leverage, P=0.3051

Appendix B – Sample Statistical Analysis for Research Question 1 (continued)

Sheet2- Oneway

Oneway Analysis of abs. val. resid. By Treatment



Oneway Anova

Summary of Fit

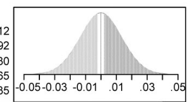
Rsquare	0.000279
Adj Rsquare	-0.01059
Root Mean Square Error	0.065629
Mean of Response	0.091433
Observations (or Sum Wgts)	94

t Test

1-2

Assuming equal variances

Difference	0.00217	t Ratio	0.160312
Std Err Dif	0.01354	DF	92
Upper CL Dif	0.02906	Prob > |t|	0.8730
Lower CL Dif	-0.02472	Prob > t	0.4365
Confidence	0.95	Prob < t	0.5635



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Treatment	1	0.00011069	0.000111	0.0257	0.8730
Error	92	0.39626198	0.004307		
C. Total	93	0.39637268			

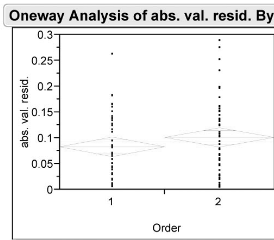
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	47	0.092518	0.00957	0.07351	0.11153
2	47	0.090348	0.00957	0.07133	0.10936

Std Error uses a pooled estimate of error variance

Sheet2- Oneway

Oneway Analysis of abs. val. resid. By Order



Oneway Anova

Summary of Fit

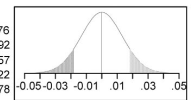
Rsquare	0.019844
Adj Rsquare	0.00919
Root Mean Square Error	0.064984
Mean of Response	0.091433
Observations (or Sum Wgts)	94

t Test

1-2

Assuming equal variances

Difference	-0.01830	t Ratio	-1.36476
Std Err Dif	0.01341	DF	92
Upper CL Dif	0.00833	Prob > |t|	0.1757
Lower CL Dif	-0.04493	Prob > t	0.9122
Confidence	0.95	Prob < t	0.0878



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Order	1	0.00786548	0.007865	1.8626	0.1757
Error	92	0.38850720	0.004223		
C. Total	93	0.39637268			

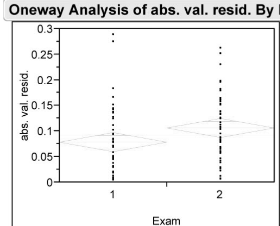
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	46	0.082089	0.00958	0.06306	0.10112
2	48	0.100388	0.00938	0.08176	0.11902

Std Error uses a pooled estimate of error variance

Sheet2- Oneway

Oneway Analysis of abs. val. resid. By Exam



Oneway Anova

Summary of Fit

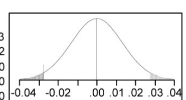
Rsquare	0.045035
Adj Rsquare	0.034655
Root Mean Square Error	0.064143
Mean of Response	0.091433
Observations (or Sum Wgts)	94

t Test

1-2

Assuming equal variances

Difference	-0.02756	t Ratio	-2.08293
Std Err Dif	0.01323	DF	92
Upper CL Dif	-0.00128	Prob > |t|	0.0400
Lower CL Dif	-0.05384	Prob > t	0.9800
Confidence	0.95	Prob < t	0.0200



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Exam	1	0.01785065	0.017851	4.3386	0.0400
Error	92	0.37852203	0.004114		
C. Total	93	0.39637268			

Means for Oneway Anova

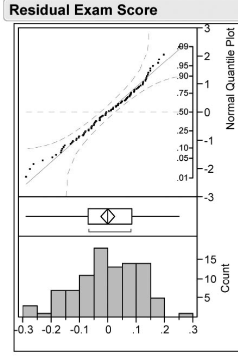
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	47	0.077652	0.00936	0.05907	0.09623
2	47	0.105213	0.00936	0.08663	0.12380

Std Error uses a pooled estimate of error variance

LatinSquare- Distribution

Distributions

Residual Exam Score



Quantiles

100.0%	maximum	0.2511
99.5%		0.2511
97.5%		0.1913
90.0%		0.1392
75.0%	quartile	0.0851
50.0%	median	-0.0007
25.0%	quartile	-0.0703
10.0%		-0.1582
2.5%		-0.2697
0.5%		-0.2881
0.0%	minimum	-0.2881

Moments

Mean	8.858e-18
Std Dev	0.1127472
Std Err Mean	0.011629
upper 95% Mean	0.0230929
lower 95% Mean	-0.023093
N	94