Effectiveness of a Writing-Based Quality Enhancement Plan in a Senior-Level Undergraduate Engineering Laboratory Setting

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Abstract

This research paper assesses the effectiveness of a writing-based quality enhancement plan implemented in a senior-level undergraduate mechanical engineering laboratory based course. The purpose of the quality enhancement plan is to enhance effective writing skills in undergraduate students through a discipline-specific recursive writing process. The effectiveness of the quality enhancement plan is assessed via two distinct student learning outcomes. The first student learning outcome assesses students' ability to demonstrate argumentation, analysis, and synthesis skills in their writing. The second student learning outcome assesses students' participation in the writing process. Over a two-semester period, students in three different sections of a senior-level mechanical engineering laboratory were evaluated based on these two student learning outcomes. In order to evaluate the first student learning outcome, students completed two individual technical reports – one at the beginning of the semester, and a second at the end of the semester. A statistical analysis of the results indicated that students did not show a statistically significant improvement in any category of student learning outcome one. In order to evaluate the second student learning outcome, students completed two process writing surveys – one at the beginning of the semester, and a second at the end of the semester. A statistical analysis of the results indicated that students showed a statistically significant improvement in the "researching," "collaborating," and "revising" components of student learning outcome two. The implementation of the quality enhancement plan as well as suggestions for improvement will be discussed.

Keywords

Quality Enhancement Plan, Technical Writing, Writing Effectiveness, Laboratory Writing

Introduction

This research paper assesses the effectiveness of a writing-based quality enhancement plan implemented in a senior-level undergraduate mechanical engineering laboratory based course. The purpose of the quality enhancement plan is to enhance effective writing skills in undergraduate students through a discipline-specific recursive writing process. The Quality Enhancement Plan (QEP) has three goals which seek to create more effective writing skills in the disciplines. The three goals are:

1. Enhance a culture of writing and critical thinking skill across the University.

2. Graduate students with stronger writing skills that transfer to the workplace and beyond.

3. Link students and faculty with the resources they need to ensure writing excellence.

The QEP is a university-wide endeavor and at least sixty percent of the undergraduate degree programs offered at the university will be phased into the program over a period of three years. The programs that are currently participating in the QEP are known as Writing Enrichment Programs (WEP). The effectiveness of the quality enhancement plan is assessed via two distinct student learning outcomes. The First Student Learning Outcome (SLO 1) assesses students' ability to demonstrate argumentation, analysis, and synthesis skills in their writing. The Second Student Learning Outcome (SLO 2) assesses students' participation in the writing process. The first and second student learning outcomes are:

1. Students will demonstrate argumentation, analysis, and synthesis skills through writing in a variety of contexts by:
    a. communicating a clearly defined purpose;
    b. pursuing a substantial or compelling inquiry;
    c. identifying, evaluating, and selecting credible evidence or relevant examples;
    d. organizing ideas and information consistent with the purpose;
    e. demonstrating a nuanced understanding of audience(s) and word choice;
    f. adhering to acceptable mechanical, structural, and format style guidelines appropriate to the discipline and purpose; and
    g. using effective visual representations to enhance, focus, and amplify written communication and text.
2. At the completion of the Writing-Enriched course(s), a greater percentage of students will voluntarily engage in the processes of writing through the use of
    a. Researching
    b. Drafting
    c. Reflecting
    d. Collaborating
    e. Revising
    f. Editing

Participating programs in the QEP commit to offering three required "writing-enriched" courses of which two must be sequenced courses (one is perquisite of the other) within the program. Ideally, these three courses span out from sophomore to senior level in order to track student performance. Writing-enriched courses are taught by Writing Enrichment Faculty (WEF) who are a group of self-identified faculty with a strong commitment to the integration and enhancement of writing in the classroom as a method for furthering student learning and preparing students for the demands of the workplace and/or graduate school.

Course Information

The Mechanical Engineering Department offers a senior-level "writing-enriched" course focused on laboratory activities in support of instruction in fluid mechanics, thermodynamics, and heat transfer. The course, MENG 4210, is entitled "Energy Science Laboratory". The laboratory course is a one credit hour course which meets once per week for one hour and fifty minutes. The pre-requisites for the course, which must be passed with a grade of "C" or better, are: fluid mechanics, thermodynamics, heat transfer, and mechatronics. Enrollment in the course is typically limited to no more than twenty students per section. On average, four sections are offered per semester. The course under consideration in this study is the third of three writing-enriched laboratory courses within the Mechanical Engineering program. The other two courses, MENG 3331 Material Science Studio and MENG 3531 Mechatronics Studio Laboratory, are junior-level laboratory courses that are intended to be taken during a students' fifth and sixth semester respectively.

In order to evaluate the effectiveness of the QEP in this senior-level laboratory course, a sample of three different sections of the course offered during the past year, all taught by the same instructor, have been selected for evaluation. First, a statistical analysis was performed in order to determine if the three different sections consisted of students with similar Grade Point Averages (GPA) and course loads (in terms of credit hours). A t-test, comparing sections "A" and "B" can be seen in Table 1 while a t-test, comparing sections "B" and C" can be seen in Table 2. For the statistical analysis a 95 % confidence interval was utilized. Each course consisted of 17 students.

Table 1. t-Test: Paired Two Sample for Means ($n = 17$, $df = 16$, $\alpha = 0.05$, $H0 = 0$) Comparing GPA and Course Loads for Sections "A" and "B"

	GPA		Hours	
	A	B	A	B
Mean	2.91	3.12	13.94	13.94
Variance	0.16	0.32	6.56	5.56
t Stat	-1.22		0.00	
P(T<=t) one-tail	0.12		0.50	
t Critical one-tail	1.75		1.75	
P(T<=t) two-tail	0.24		1.00	
t Critical two-tail	2.12		2.12	

After comparing the three different sections of the course it was determined that there was not a statistically significant difference in student quality (based on GPA) or student workload (based on credit hours enrolled) between the three sections. Therefore, when evaluating SLO 1 and SLO 2 the three sections will be grouped together yielding a total of 51 students (17 from each section). In order to avoid instructor bias, the same instructor taught, and evaluated, all three sections. It should be noted that while the students took statistically similar course loads this does not account for student employment (i.e. part-time jobs or internships were not accounted for).

Table 2. t-Test: Paired Two Sample for Means ($n = 17$, $df = 16$, $\alpha = 0.05$, $H_0 = 0$) Comparing GPA and Course Loads for Sections "B" and "C"

	GPA		Hours	
	B	C	B	C
Mean	3.12	3.07	13.94	13.82
Variance	0.32	0.13	5.56	4.15
t Stat	0.24		0.17	
P(T<=t) one-tail	0.41		0.43	
t Critical one-tail	1.75		1.75	
P(T<=t) two-tail	0.81		0.87	
t Critical two-tail	2.12		2.12	

Student Learning Outcome 1 (SLO 1)

SLO 1 is evaluated via a rubric based assessment of student writing which can be seen in the Appendix. Students are evaluated on two individual technical reports – one at the beginning of the semester and a second at the end of the semester. The rubric used for the assessment of the individual technical reports also contains sections that are not pertinent to the QEP but are relevant in engineering laboratory courses (e.g. experimental uncertainty). In the rubric, students are evaluated on a scale of 1 to 5. The students are provided a copy of the rubric at the beginning of the course. However, presently students do not perform a self-assessment activity to acclimate to the rubric. In order to account for the scale utilized in the rubric a composite average for each SLO 1 was calculated as follows:

$$\begin{aligned} \mathit{Composite\ Average} &= (\%\ \mathit{of\ Students\ at\ Level}\ 5) \times 5 + (\%\ \mathit{of\ Students\ at\ Level}\ 4) \times 4 \\ &+ (\%\ \mathit{of\ Students\ at\ Level}\ 3) \times 3 + (\%\ \mathit{of\ Students\ at\ Level}\ 2) \times 2 \\ &+ (\%\ \mathit{of\ Students\ at\ Level}\ 1) \times 1 \end{aligned}$$

The results from the rubric-based assessment of the students' technical writing can be seen in Figure 1. Unfortunately, students did not improve in any of the areas assessed in the rubric. However, while there is an observable (based on the figure) decrease in the level of writing that the students' achieved the decrease is not statistically significant. Thus, it cannot be determined if the quality of student writing in the individual technical reports increased or decreased.

It is hypothesized that the lack of improvement can be at least partially attributed to the number of individual writing assignments utilized in the course. Students only complete two individual writing assignments in the course – one at the beginning of the course and a second at the end. The remaining eight writing assignments which are assigned in between the two individual reports are group technical reports. As this is an engineering course, students are encouraged to work in groups as they would in their careers. Schulz and Ludlow[1] found that group writing is an integral part of the engineering workplace that is often neglected in undergraduate engineering curricula. They observed different traditional group writing styles and found that group dynamics, leadership, and group members' views towards revision were prevailing factors that determined the success of a group writing activity. They also noted that students may often take on the work load of under-performing group members which can lead to a reduction in the quality of the written documents as the semester progresses due to one or more students carrying additional workload.

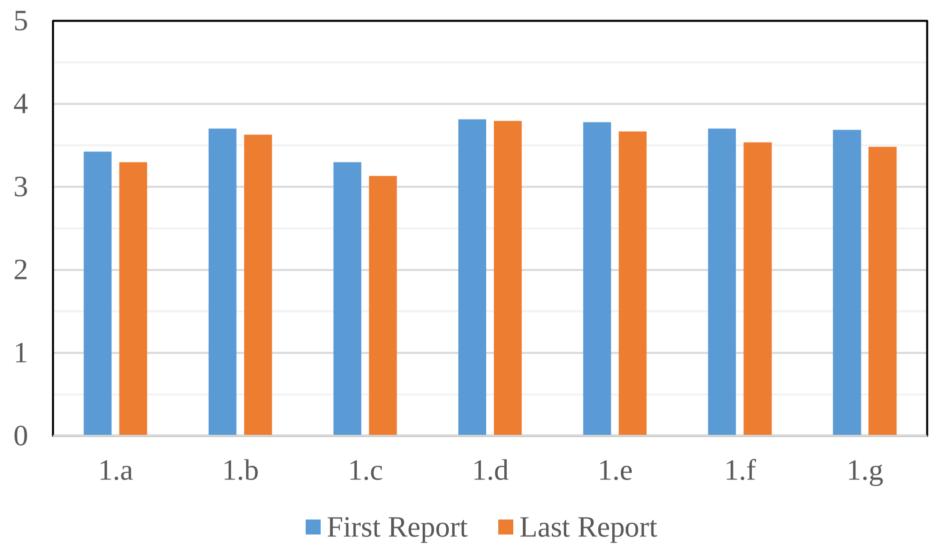

Figure 1. Rubric-Based Assessment of Student Writing for SLO 1

It has been observed by the instructor, albeit qualitatively, that when students complete group writing assignments the students assign individual sections of the report to each other. The students then complete the same section of the report throughout the course. For example, "Student A" may always complete the abstract while "Student B" always completes the introduction. Through repetition the students may have demonstrated an increase in the quality of their writing – in their self-assigned section(s). However, at the end of the semester when a student must once again submit an individual report the student is still unfamiliar with other sections of the report which they may not have contributed to during the course of the semester. As such, in order to positively impact student writing in an engineering laboratory setting more individual writing assignments may need to be utilized. It has also been observed by the instructor, again qualitatively, that students often exhibit an increase in the level of apathy towards their writing assignments as the semester progresses. Based on student feedback this may be attributed to the relatively high work load associated with the course. Students may feel that a one credit hour laboratory course does not deserve, or merit, the same amount of effort as a traditional three credit hour lecture course.

Finally, Hawkins et al.[2] found that students may benefit more through "incidental writing" than from formal writing. As formal writing processes in a laboratory setting typically occur after the completion of an experimental activity students may feel that the formal writing, and the writing process itself, is a secondary activity. In regard to the evaluation of these incidental writing assignments, Hawkins et al. recommend focusing more on the content of the writing rather than on its grammatical correctness or stylistic expression as students may be able to focus more on comprehending the subject rather than communicating it in an error-free manner. Unfortunately, the QEP in place directly assesses adherence to acceptable mechanical, structural, and format style guidelines (SLO 1.f).

Student Learning Outcome 2 (SLO 2)

SLO 2 is assessed via a process writing survey which is distributed to students the first week of the semester and the final week of the semester. In the process writing survey students are asked how frequently they engaged in the following activities voluntarily, without explicit instruction:

a. Researching (gathering and evaluating relevant information)

b. Drafting (creation of the early or preliminary draft)

c. Reflecting (rereading drafts/comments and planning potential changes)

d. Collaborating (conferring with others to elicit their feedback)

e. Revising (creating multiple improving? progessive? versions to address reasoning, logical, audience, and flow of ideas)

f. Editing (correcting grammar and mechanical errors)

Students rate their engagement in the above activities on a scale of 1 to 6:

1. Never
2. Very Rarely
3. Rarely
4. Occasionally
5. Usually
6. Always

A statistical analysis was again performed to determine if the students engaged more frequently in the process writing activities outlined above. The results from the statistical analysis of the first and last processing writing survey can be seen in Tables 3 and 4.

A comparison of the improvement in student perception of their participation in the various process writing activities can be seen in Figure 3. As can be seen in Figure 3, students believed they were more active in all parts of the writing process. Unfortunately, the null hypothesis was only rejected in three of the six process writing activities. Students showed statistically significant improvement in: researching, collaborating, and revising. Students did not show a statistically significant improvement in: drafting, reflecting, or editing. Interestingly, while students perceived that they engaged in the aforementioned process-writing activities more frequently, they did not achieve statistically higher ratings in the rubric based assessment of their technical writing as outlined in SLO 1 results.

It is believed that students showed a statistically significant improvement in the "researching" section of the report because students were tasked with sourcing background material when writing the introduction section of their reports. As the laboratory course primarily consists of group experiments and group reports it came as no surprise that the students showed improvement in "collaborating." Students receive detailed feedback on each section of their report and thus it was expected that students would also show improvement in "revising."

Table 3: t-Test: Paired Two Sample for Means (n = 51, df = 50, $\alpha = 0.05$, $H_0 = 0$) for Research, Drafting, and Reflecting on Process Writing Survey

	Researching 2.a		Drafting 2.b		Reflecting 2.c	
	First	Last	First	Last	First	Last
Mean	4.63	5.08	4.14	3.94	4.31	4.61
Variance	2.04	0.55	2.24	2.10	1.94	1.48
t Stat	-1.96		0.62		-1.03	
P(T<=t) one-tail	0.03		0.27		0.15	
t Critical one-tail	1.68		1.68		1.68	
P(T<=t) two-tail	0.06		0.54		0.31	
t Critical two-tail	2.01		2.01		2.01	

Table 4: t-Test: Paired Two Sample for Means (n = 51, df = 50, $\alpha = 0.05$, $H_0 = 0$) for Collaborating, Revising, and Editing on Process Writing Survey

	Collaborating 2.d		Revising 2.e		Editing 2.f	
	First	Last	First	Last	First	Last
Mean	4.24	4.82	4.18	4.90	4.90	5.22
Variance	2.02	1.51	2.67	1.17	1.97	0.65
t Stat	-2.07		-2.48		-1.32	
P(T<=t) one-tail	0.02		0.01		0.10	
t Critical one-tail	1.68		1.68		1.68	
P(T<=t) two-tail	0.04		0.02		0.19	
t Critical two-tail	2.01		2.01		2.01	

The biggest disappointment, from the instructor's point of view, was the lack of improvement in "reflecting." A major weakness in the students' technical writing was their inability to reflect on and interpret the physical significance of their results in the discussion section of their report. It was evident that students were capable of reporting their results but not reflecting on their interpretation.

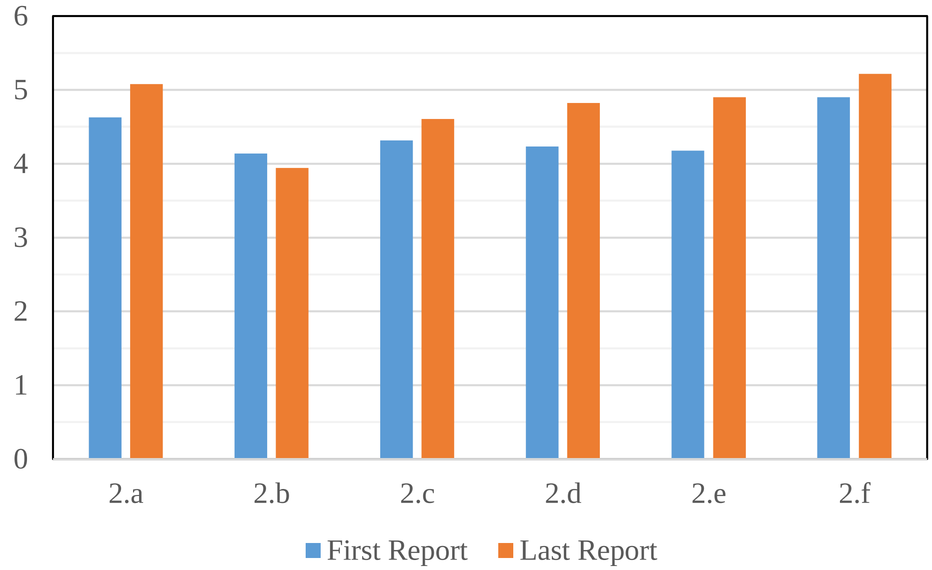

Figure 2. Survey-Based Assessment of Process Writing Activities for SLO 2

Additional Insight into the Quality Enhancement Plan

There are numerous resources available to students outside of the classroom that they may utilize to improve their writing. For example, a university-supported writing center provides students the opportunity to obtain individualized feedback on their writing from teachers of writing at the university. Students in any course, and at any stage of the writing process, can visit this writing center to receive advice on how to improve their writing. The instructor has found that students do not take advantage of this service which may be attributed to the center's lack of discipline-specific technical support. Walker[3] presented the establishment of a writing center within an electrical and computer engineering department and found that a department-centric center is more effective than a center which serves the general student body. The writing center, in collaboration with laboratory instructors, focused on specific laboratory assignments as they were assigned. In addition to the writing center, students also have access to a Student Writing Fellow (SWF). At the time, the SWF available to the program was a lower level undergraduate student. Students may find it more desirable to seek assistance from a graduate student who may have more experience with technical writing due to the level of writing required to disseminate graduate level research.

Finally, an alternative pedagogical approach may need to be utilized to improve performance. Yalvac et al.[4] found that a How People Learn (HPLC) pedagogical approach in a Writing Across the Curriculum (WAC) or Writing within the Disciplines (WID) can promote learning in writing.

Yalvac et al. confirmed that simply integrating writing instruction into a course does not help students obtain the more advanced writing skills that they may need in their profession. Yalvec et al. found that in order to teach synthesis and argumentation writing instruction must be learner and community centered. The authors concluded that in order to encourage students to improve their writing skills instructors should: use embedded assignments, provide adequate time for student reflection, and employ an interactive, coaching pedagogy.

Conclusion

The effectiveness of a writing-based quality enhancement plan as implemented in a senior-level undergraduate mechanical engineering laboratory was assessed based on two student learning outcomes. The first student learning outcome assessed students' ability to demonstrate argumentation, analysis, and synthesis skills in their writing. The first student learning outcome was evaluated via a rubric-based assessment of individual technical reports. The second student learning outcome assessed students' participation in the writing process. The second student learning outcome was evaluated via a process writing survey distributed at the beginning and the end of the semester. In regard to the first student learning outcome, students did not show a statistical increase, nor decrease, in the quality of their writing as assessed via the rubric. However, in regard to the second student learning outcome, students showed a statistically significant increase in their perceived level of activity in the following three components of the writing process: researching, collaborating, and revising.

References

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4 Yalvac, B., H.D. Smith, J.B. Troy, and P. Hirsch, "Promoting Advanced Writing Skills in an Upper-Level Engineering Class," Journal of Engineering Education, vol. 96, no. 2, 2007, pg. 117-128.

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Appendix

Table 4. Rubric for Individual Technical Reports with Student Learning Outcomes

	Level 1	Level 2	Level 3	Level 4	Level 5
Abstract (SLO 1.b)	An abstract is not included.	An abstract is included but does not include objective, methodology, and major findings.	The abstract, while present, does not include major findings and/or includes inappropriate content.	The abstract includes general content and findings but may lack in some areas.	The abstract is an appropriate balance between overview content and specific findings. It is an insightful summary of the report.
Introduction (SLO 1.a)	A technical introduction is not included or contains inappropriate content. No purpose stated.	A technical introduction is present but does not include theoretical background, relevant equations, and/or includes incorrect information. Content related but no clear purpose.	Introduction contains some theoretical background but misses some major points (background theory or relevant equations). Purpose present but weak.	Introduction is present and appropriately conveys theoretical background, including equations. Minor attempt to incorporate material beyond the laboratory handout. Purpose is evident.	Introduction complete and well written. Includes theoretical background equations. Presents appropriate content not included in the laboratory handout. Purpose clearly defined.
Experimental Methods	An experimental methods section is not present. A schematic is also absent.	An experimental method section is present but lacks sufficient detail and/or an experimental schematic is not present.	An experimental method section and schematic are present but lack sufficient detail to replicate the experiment.	An experimental method section and schematic clearly represent the methodology followed but some minor details are absent.	Sufficient detail to replicate the experiment is present in the experimental methods and schematic.
Data	Data not reported.	Some, but not all, of the data is presented. Data may contain several major errors (units, significant digits, etc.)	All of the data is represented but contains several minor or a few significant errors (units, significant digits, etc.)	All of the data is presented but may contain a few minor mistakes (units, significant digits, etc.)	The data is fully presented (all trials) and reported using appropriate units and significant digits.

Table 4. Rubric for Individual Technical Reports with Student Learning Outcomes (Continued)

Results	Results section is not present.	Significant portions of the results section are absent. Significant sample calculations contain significant errors or are absent.	All required results are presented but there are some significant errors in sample calculations and/or some calculations are absent.	Results contain minor errors but all sections are present and in a logical order. All sample calculations are included but may contain minor errors (variable form, units, etc.)	Results are presented without error. The results section is well written and presented in a logical manner. All sample calculations are included and correct.
Discussion (SLO 1.c)	No discussion/ reflection present and/or not related to the results and the overall purpose	Results summarized but are vaguely discussed and inconsistent with the purpose.	All results are summarized, but limited support is provided to contribute to the main purpose.	Results summarized. Some attempt at communicating physical significance. Discussion supports main purpose	Insightful discussion, synthesis and reflection on the physical significance of the results and it fully supports the overall purpose
Experimental Uncertainty/Statistical Analysis in Discussion	Experimental uncertainty and statistical analysis absent.	Experimental uncertainty or statistical analysis absent, may contain major errors.	Experimental uncertainty and statistical analysis present but in insufficient detail, may contain significant errors.	Experimental uncertainty and statistical analysis present in sufficient detail but may contain minor errors.	Experimental uncertainty and statistical analysis present in sufficient detail and without error.
Conclusion	Conclusion not presented.	Conclusion present but contains inappropriate information or lacks major findings.	Conclusion present and contains appropriate sections but findings are not adequately presented	Conclusion present and contains appropriate findings but lacks sufficient detail.	Conclusion presented in a logical, concise manner and contains appropriate detail when conveying major findings.
Used effective visual representations to enhance, focus, and amplify written text (SLO 1.g)	Tables and figures not present.	Tables and figures present but used inappropriately and/or visuals do not clearly convey information	Tables and figures attempt to convey results appropriately but presentation is distracting and some information may be incorrect	Tables and figures convey results appropriately.	Tables and figures convey results and greatly enhance the written text.

Table 4. Rubric for Individual Technical Reports with Student Learning Outcomes (Continued)

Adhered to acceptable spelling, grammar, mechanics, sentence structure, tense etc.	Significant and frequent errors throughout in spelling, grammar, sentence structure, tense, etc. Clear lack of proof reading.	Multiple errors in spelling, grammar, sentence structure, tense etc.	Few errors in spelling, grammar, sentence structure, tense, etc.	Minor noticeable or distracting errors in spelling, grammar, sentence structure, tense, etc.	No errors in spelling, grammar, sentence structure, tense, etc.
Adhered to acceptable style and format guidelines as defined by ASME (SLO 1.f)	Lack of adherence, or knowledge of, ASME guidelines.	Minimal attempt at adhering to ASME guidelines.	ASME guidelines generally adhered to. Some style and format errors present.	Clear attempt at adhering to ASME guidelines. Minor inconsistencies present.	ASME style and format guidelines clearly adhered to.
Audience, word choice, and terminology (SLO 1.e)	Inappropriate, or inconsistent audience and/or word choice. Technical terminology absent.	An attempt to write towards an appropriate audience was made.	Writes towards an appropriate audience but fails to consistently use technical terminology and word choices.	Writes towards an appropriate audience and attempts to use correct technical terminology and word choices but minor lapses are present.	Demonstrates an ability to write towards a specific audience and uses appropriate technical terminology.
Organization of information consistent with purpose (SLO 1.d)	Sections are not organized and/or section content does not contribute to purpose.	An attempt was made to organize sections appropriately but sections do not contribute to purpose.	Sections are appropriately organized but more than one section does not contribute to the purpose.	Sections are organized appropriately but one section may not contribute to the purpose.	Each section is organized and clearly contributes to the purpose.