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Effectiveness of Checklists in Developing Technical Writing Skills

Dr. Gautom Kumar Das, University of Maryland Baltimore County

Dr. Gautom Das is an Associate Teaching Professor in the Chemical, Biochemical and Environmental Engineering at UMBC. Prior to joining UMBC, he was a Research Scientist and Lecturer in the Chemical and Biomolecular Engineering at Rice University, and a Post-doctoral Scholar at the University of California, Davis. He earned his PhD in Chemical and Biomolecular Engineering from the Nanyang Technological University (NTU), Singapore. He has worked in research laboratories in the US, Canada, and Singapore; his previous research interests were on nanomaterials for multimodal and deep tissue imaging, and biosensing applications.

Work-in-progress: Effectiveness of Checklists in Developing Technical Writing Skills

1. Introduction

Writing laboratory reports is a foundational skill for undergraduate students in science and engineering disciplines that has long been emphasized by the National Academies, ABET, and professional organizations such as American Institute of Chemical Engineers [1-4]. However, as laboratory instructors, we have often been less than satisfied with both the process of guiding students in report writing and the quality of their submissions. Common challenges include encountering students failing to include required content, lacking logical organization, and the difficulty for instructors to provide effective feedback within limited time constraints.

The most common approach in writing-intensive courses is instructors provide written feedback on student's writing, which students typically prefer. However, one of the key challenges of providing meaningful feedback is that instructors require a complete report. Although writing feedback is the main mechanism how we teach students writing, the balance is important. For example, previous research suggests that instructor's intervention at every stage of writing can reduce students' self-reliance in developing their own writing skills [5]. They suggested self-assessment strategies which force students to take greater responsibility for their work, and active engagement in the writing and editing process [6]. Various other strategies have been reported in the literature to support student writing, including peer-reviewing [7], writing-to-learn approaches, partnering with library [8], the use of writing tutors, [9] and the creation of specific assessment rubrics for written communication [10-12].

Rubrics serve as a great tool to convey expectations regarding student work. While rubrics are valuable tools for setting clear expectations, they do not always ensure that students would include all essential components in their reports. Our previous data indicate that rubrics alone are insufficient in guiding students to include all requirements in every section. We believe that colleagues at other institutions encounter similar difficulties.

In response to these challenges, we explored a checklist-based approach to support students in developing their writing skills. At our institution, upper-level (400-level) laboratory courses are designated as Writing Intensive (WI) to prepare students for technical writing. We developed a generic checklist to guide students through the report-writing process. Our goal is to further refine and assess the effectiveness of this checklist. We designed it to serve multiple functions: as a reference tool for students during report preparation, a self-review guide prior to submission, and a fair and efficient grading tool for instructors.

It is important to distinguish between rubrics and checklists. Rubrics provide scoring guidelines that outline performance criteria for a task, while checklists are simple lists of specific elements that should be included in an assignment. Checklists can serve as quick-reference tools to ensure that all necessary components are covered. Our checklist prompts students to mark each required element to cross off completed items.

In this work-in-progress study we share our efforts to develop and implement this writing checklist, focusing on its potential to address the challenges indicated above. Specifically, we investigated the following research questions:

(1) Does the inclusion of a checklist help students submit reports that are more complete?
(2) Does the inclusion of a checklist improve the quality of the reports as reflected in their grades?

Through this study, we aim to understand both instructor and student perspectives on the usefulness of the checklist and explore best practices for its implementation in laboratory courses.

2. Methods

2.1 Data Collection

This study was conducted in a senior chemical engineering laboratory course, a regular fall semester offering at the author's institution. The dataset analyzed was from the Fall 2024 semester (N = 24). The course consisted of a 75-minute weekly lecture and a 4-hour laboratory component. During the lecture, faculty instructors reviewed upcoming experiments and discussed various aspects of data analysis, presentation, and scientific writing. The course was co-taught by three instructors; however, the study was conducted by the authors of this paper.

Students performed laboratory exercises under the guidance of a faculty instructor and graduate teaching assistants. The course consisted of six laboratory experiments focusing on fundamental concepts of chemical and environmental engineering. For this study, two relatively open-ended experiments were selected: (i) Dye Sensitized Solar Cells: Students created prototypes of dye-sensitized solar cells and tested them for efficiency. (ii) Controlled Drug (Dye) Release: Students investigated dye release from alginate beads over time, simulating controlled drug delivery.

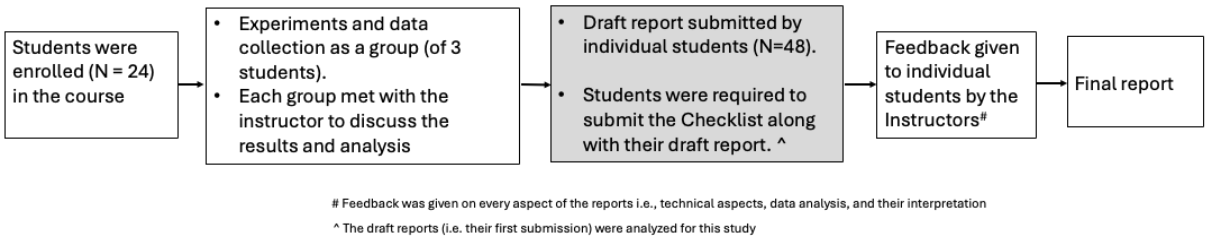

Figure 1. A general schematic of the assessment process for this study

A general schematic of the experiment, report writing, and assessment process is shown in Figure 1. Students discussed their experimental results with instructors and teaching assistants before writing their draft reports i.e. first submission. The draft reports were graded using a standard rubric. If a report received less than 80% of the available points, students were required to revise it, addressing the instructor's comments. The revised report, submitted as the final version, was regraded to determine the final grade. Students were instructed to use the Checklist (provided in Appendix A) to prepare both the draft report and final report.

It is noteworthy that students were allowed to use generative AI tools (e.g., ChatGPT) during any stage of the writing process or they could choose not to use them. If AI assistance was used, students were asked to include the following information in the Appendix of their reports: the prompt(s) used, and other details on how the AI-assisted content was incorporated or revised. This information was collected to ensure the accuracy of the report content and the authenticity of references.

2.2 Instructor's Assessment

A total of 48 draft reports (i.e., first submission) were evaluated for this study. Reports in which students self-reported the Checklist were analyzed further for this study.

3. Results and Discussion

As mentioned earlier, the primary goal of this study was to evaluate the effectiveness of the checklist in laboratory report writing. To begin, we examined the extent to which students

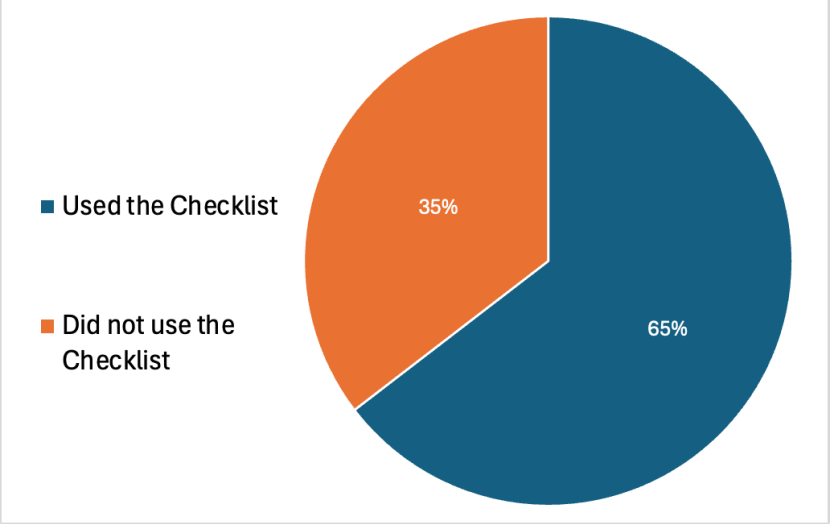

Figure 2. The percentage of students who submitted (or did not submit) the checklist with their draft reports.

utilized the checklist, as determined by its inclusion in their reports. Figure 2 shows the overall percentage of students who submitted the checklist with their draft reports. Interestingly, approximately 35% of students did not include the checklist.

Next, we analyzed how students engaged with the checklist i.e. whether they simply checked the boxes or actively used it to guide their report writing. Among those who submitted their checklists, about 60% demonstrated effective use, as reflected in the quality of their reports (i.e., quality of figures and plots presented, writing of each section, and the overall report grades). The remaining 40% included the checklist but did not consistently mark the sections related to report content or missing contents.

To further illustrate these findings, Appendix B provides anonymized examples of student work, including completed rubrics (Figure S1), instructor comments on the missing contents or incorrect analysis as per the checklist (Figure S2), and a sample rubric with instructor feedback and corresponding report grades (Table S1).

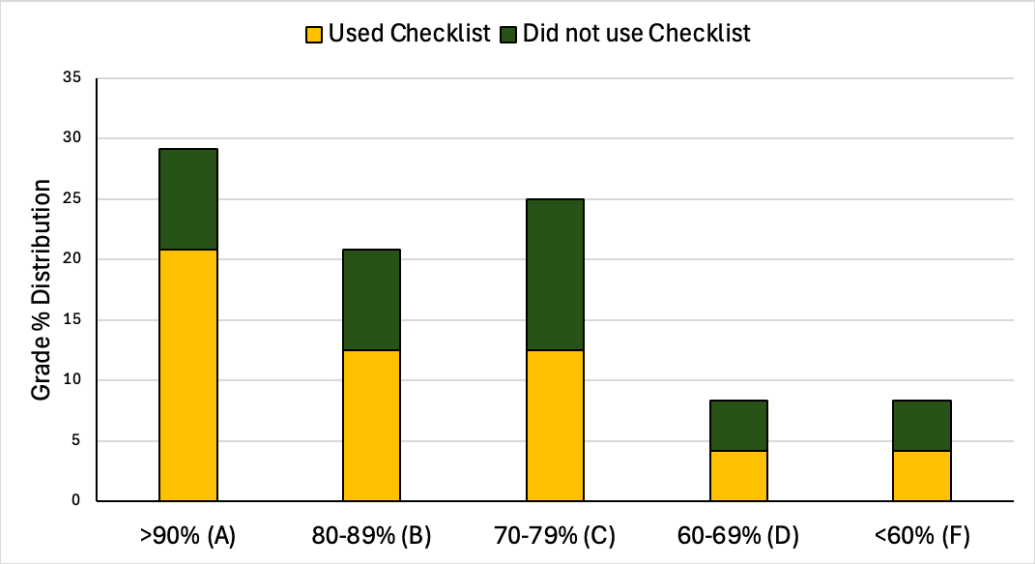

Figure 3. The grade distribution for students who used the checklist (yellow) versus those who did not (dark green).

We then examined the correlation between the use of the checklist and students' report grades. Figure 3 presents the distribution of grades for students who used the checklist (yellow) versus those who did not (dark green). Notably, both groups had representations across all grade brackets. However, among students receiving unsatisfactory grades (defined as 79% or lower per the course policy), the proportions were similar between the two groups e.g., 12.5% from each category within the 25% of reports that earned a “C” grade. On the other hand, students who earned “A” and “B” grades were disproportionately more likely to have used the checklist as part of their report-writing process, indicating its potential effectiveness for higher-performing students.

Lastly, we compared the grades of the current cohort (Fall 2024) with those of a control group from Fall 2023, where all factors (e.g. instructor, rubrics, class format) were identical except for the implementation of the checklist. Figure 4 reveals compelling results: the study group (Fall 2024) achieved an average grade of 79.6 ± 13.5, compared to an average grade of 68.4 ± 32.2 for the control group (Fall 2023). Additionally, the median grade was higher for the study group, and also exhibited a narrower grade distribution.

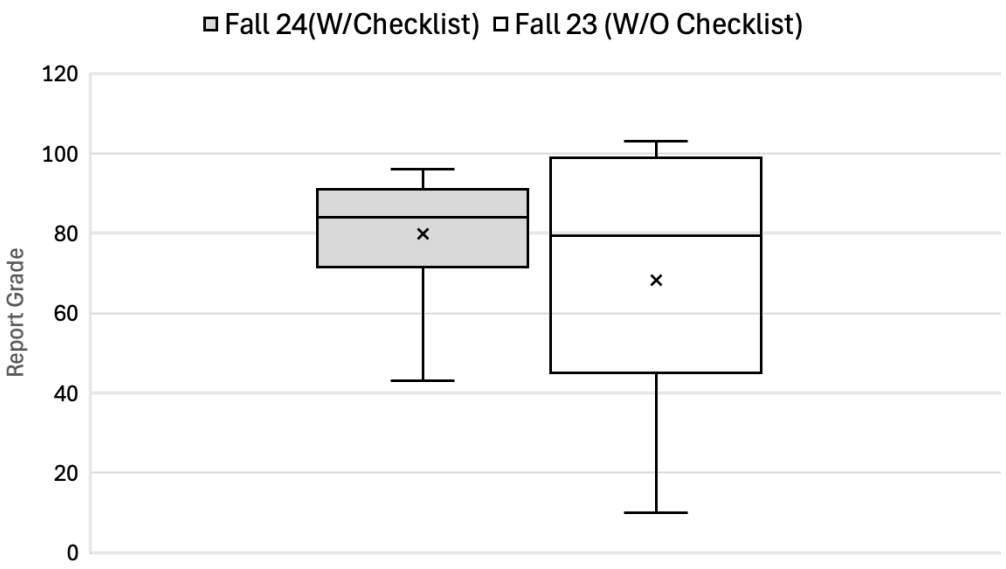

Figure 4. Report grades of the study group (Fall 2024) vs a control group (Fall 2023). For the study group average grade was 79.6 ± 13.5, compared to an average grade of 68.4 ± 32.2 for the control group.

4. Conclusion

Although we have just begun using this checklist, initial data are very encouraging which suggests that incorporating a checklist into laboratory report writing can be beneficial, particularly for higher-achieving students. However, we need a more in-depth study to understand its potential.

Moving forward, we want to engage students in refining the checklist and incorporate their feedback to refine the list. A more strategic approach is required to support students in the bottom half of the class. With collective input from instructors and students, we envision developing a versatile checklist template that can be tailored to meet the unique requirements of writing assignments across various disciplines.

5. References

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APPENDIX A

CHECK LIST

Instruction. Please put an 'X' next to the items on the checklist. Please sign on Page 2

Page limit: 10 pages of written text. Figures, tables, pictures, abstract, title page, appendices and references do not count towards page limit.

Title Page (does not count against page limits)

- The title page is a separate page and does not count against the page limit
- Student's name, group members' names, report revision (first or final) and day the lab was conducted.
- The title of the lab report should be descriptive of the experiment and reflect what the experiment analyzed.
    - Ex: "Determining the Free Chlorine Content of Pool Water"

Abstract (300 words, does not count against page limits)

Abstracts are a summary of the experiment as a whole and should familiarize the reader with the purpose of the research. Abstracts will always be written last, even though they are the first paragraph of a lab report.

- When writing an abstract, try to answer these questions:
    - Why was the research done or experiment conducted?
    - What problem is being addressed?
    - What results were found? If a list of questions that you were required to address were given these results should be summarized succinctly.
    - What are the meaning of the results?

Introduction (1-1.5 pages)

- The introduction of a lab report discusses the problem being studied and the theory that is relevant to understanding the findings.
    - For example, in the Coagulation/Flocculation lab the appropriate chemical reactions should be included and their importance summarized.
- The motivation for the research and the hypothesis of the experiment are stated in this section.
- Write the introduction in your own words. Try not to copy from a lab manual or other guidelines. Instead, show comprehension of the experiment by briefly explaining the problem.

Methods and Materials (1 page)

The methods and materials section provides an overview of any equipment, apparatus, or other substances used in the experiment, as well as the steps taken during the experiment. If using any specific amounts of materials, make sure the amount is listed. For example, pipette, graduated cylinder, 1.13mg of Na, 0.67mg Ag, include name of equipment used and model number.

- List the steps taken as they actually happened during the experiment, not as they were supposed to happen. Do **not** list the steps using bullet points, write the procedure in sentence form.
- If written correctly, another researcher should be able to duplicate the experiment and get the same or very similar results.

Results (3-4 pages)

The results show the data that were collected during the experiment.

- Present tables, figures, and pictures (if appropriate) sequentially. Tables should be labeled numerically, as "Table 1", "Table 2", etc. Other figures should be labeled numerically as "Figure 1", "Figure 2", etc. **before** you explain the data. For example:
    - The average pH and standard deviation versus alum dosage are presented in Figure 1. The pH ranged from XX to XX and decreased as the alum dosage increased. Standard deviations were below 0.12 indicating that the results from the three trials are consistent.
- All tables, figures, etc. must be introduced before discussed.
- Use statistics if appropriate.

    - For example: in the Coagulation/Flocculation lab there will be three trials. The average and STD should be graphed not the individual results from each trial.
- Typically tables, figures, etc. are embedded in the text. However this is time consuming and often hard to print correctly. Thus, tables, figures, *etc.* are included at the end of the report but must be placed in the order that they were introduced in the text. Tables, figures, *etc.,* are not counted against the page limit. A separate description on how tables, figures, *etc.* should appear is presented later in this guideline
- Calculations are not included here but should be placed in the Appendices.

Discussion (3-4 pages)

The discussion section is one of the most important parts of the lab report. It analyzes the results of the experiment and is a discussion of the data.

- If any results are unexpected, explain why they are unexpected and how they did or did not affect the data obtained.
- If there are any experimental errors, analyze them.
- Explain your results and discuss those using relevant terms and theories.
- When writing a discussion, try to answer these questions:
    - What do the results indicate?
    - What is the significance of the results?
    - Are there any gaps in knowledge?
    - Are there any new questions that have been raised?
- If a list of questions were provided by the instructor they should be addressed in this section.

Conclusion (0.5 – 0.75 pages)

- The conclusion is a summation of the experiment. It should clearly and concisely state what was learned and its importance.

References (no page limitation, does not count against page limit)

- If using any outside sources to support a claim or explain background information, those sources must be cited in the references section of the lab report.
- In the event that no outside sources are used, the references section may be left out.
- The easiest way to format references is to use the author(s) name then list the citations alphabetically in the reference section.

Report Layout

- Are sections and subsections labeled correctly
- Are my margins 1" around and am I using Times New Roman 12 font?
- Have I included page numbers and are my figures/tables/pictures presented at the end of the text?

Figures, Tables and Pictures

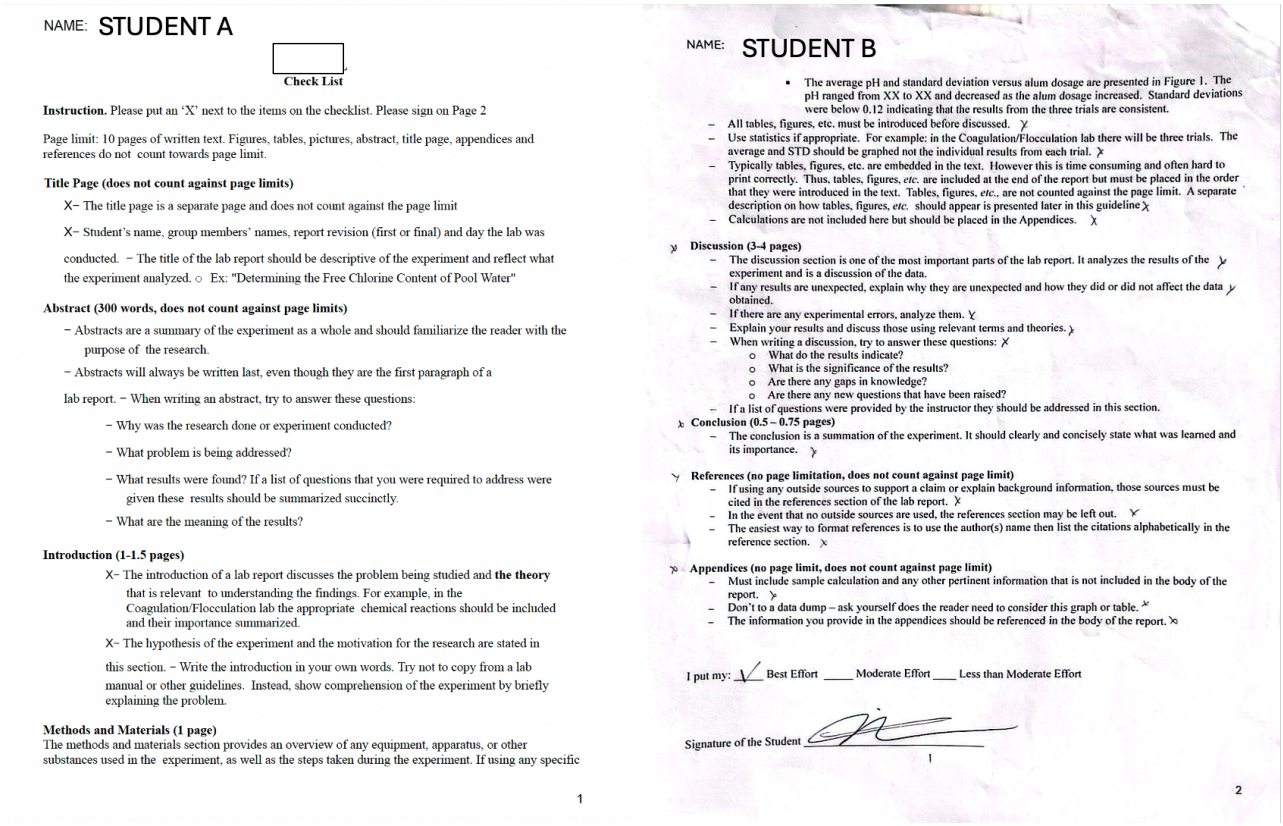
- Are axis labeled and correct units presented?
- Are data symbols large enough and STD bars presented (if appropriate)
- Am I using the correct lines (point to point if no model/regression analysis used)
- Do my tables/figures/pictures have descriptive headings?
- Are my legends needed and if yes are they appropriate if printed in black and white?
- Can I combine tables/figures/pictures to make it easier for the reader to assess my results?

Appendices (no page limit, does not count against page limit)

- Must include sample calculation and any other pertinent information that is not included in the body of the report.
- Don't to a data dump – ask yourself does the reader need to consider this graph or table.
- The information you provide in the appendices should be referenced in the body of the report.

I put my: _____ Best Effort _____ Moderate Effort ____ Less than Moderate Effort
Signature of the Student _____

APPENDIX B



NAME: STUDENT A

Check List

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X– The title page is a separate page and does not count against the page limit

X– Student's name, group members' names, report revision (first or final) and day the lab was conducted. – The title of the lab report should be descriptive of the experiment and reflect what the experiment analyzed. ○ Ex: "Determining the Free Chlorine Content of Pool Water"

Abstract (300 words, does not count against page limits)

– Abstracts are a summary of the experiment as a whole and should familiarize the reader with the purpose of the research.

– Abstracts will always be written last, even though they are the first paragraph of a lab report. – When writing an abstract, try to answer these questions:

– Why was the research done or experiment conducted?

– What problem is being addressed?

– What results were found? If a list of questions that you were required to address were given these results should be summarized succinctly.

– What are the meaning of the results?

Introduction (1-1.5 pages)

X– The introduction of a lab report discusses the problem being studied and **the theory** that is relevant to understanding the findings. For example, in the Coagulation/Flocculation lab the appropriate chemical reactions should be included and their importance summarized.

X– The hypothesis of the experiment and the motivation for the research are stated in this section. – Write the introduction in your own words. Try not to copy from a lab manual or other guidelines. Instead, show comprehension of the experiment by briefly explaining the problem.

Methods and Materials (1 page)

The methods and materials section provides an overview of any equipment, apparatus, or other substances used in the experiment, as well as the steps taken during the experiment. If using any specific

1

NAME: STUDENT B

- The average pH and standard deviation versus alum dosage are presented in Figure 1. The pH ranged from XX to XX and decreased as the alum dosage increased. Standard deviations were below 0.12 indicating that the results from the three trials are consistent.

– All tables, figures, etc. must be introduced before discussed.
– Use statistics if appropriate. For example: in the Coagulation/Flocculation lab there will be three trials. The average and STD should be graphed not the individual results from each trial.
– Typically tables, figures, etc. are embedded in the text. However this is time consuming and often hard to print correctly. Thus, tables, figures, *etc.* are included at the end of the report but must be placed in the order that they were introduced in the text. Tables, figures, *etc.*, are not counted against the page limit. A separate description on how tables, figures, *etc.* should appear is presented later in this guideline
– Calculations are not included here but should be placed in the Appendices.

Discussion (3-4 pages)
– The discussion section is one of the most important parts of the lab report. It analyzes the results of the experiment and is a discussion of the data.
– If any results are unexpected, explain why they are unexpected and how they did or did not affect the data obtained.
– If there are any experimental errors, analyze them.
– Explain your results and discuss those using relevant terms and theories.
– When writing a discussion, try to answer these questions:
  - What do the results indicate?
  - What is the significance of the results?
  - Are there any gaps in knowledge?
  - Are there any new questions that have been raised?
– If a list of questions were provided by the instructor they should be addressed in this section.

Conclusion (0.5 – 0.75 pages)
– The conclusion is a summation of the experiment. It should clearly and concisely state what was learned and its importance.

References (no page limitation, does not count against page limit)
– If using any outside sources to support a claim or explain background information, those sources must be cited in the references section of the lab report.
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– Must include sample calculation and any other pertinent information that is not included in the body of the report.
– Don't to a data dump – ask yourself does the reader need to consider this graph or table.
– The information you provide in the appendices should be referenced in the body of the report.

I put my: √ Best Effort ____ Moderate Effort ____ Less than Moderate Effort

Signature of the Student

1

2

Figure S1. Examples of student-completed checklists: Partially- (left) vs. fully- (right) filled. Identifiable information anonymized.

Checklist

From Checklist (on Report Layout)

- Are sections and subsections labeled correctly
- Are my margins 1" around and am I using Times New Roman 12 font?
- Have I included page numbers and are my figures/tables/pictures presented at the end of the text?

Instructor's comment

1. Introduction

Groundwater plays a vital role in various aspects of daily life. It serves as a primary source of drinking water for a significant portion of the population and is extensively used for irrigation and agricultural purposes. In rural areas, groundwater accounts for approximately 90% of drinking water, while 42% is utilized for irrigation [2]. Understanding and calculating groundwater flow is equally critical, as it enables the prediction of pollutant dispersion rates and the extent of their spread. The movement of water in groundwater systems can be determined using Darcy's equation, as shown below:

$$Q = KA\frac{h_1 - h_2}{L} \quad (1)$$

Commented : include section numbers per report guidelines

Checklist

Figures, Tables and Pictures

- Are axis labeled and correct units presented?
- Are data symbols large enough and STD bars presented (if appropriate)
- Am I using the correct lines (point to point if no model/regression analysis used)
- Do my tables/figures/pictures have descriptive headings?
- Are my legends needed and if yes are they appropriate if printed in black and white?
- Can I combine tables/figures/pictures to make it easier for the reader to assess my results?

Instructor's comment

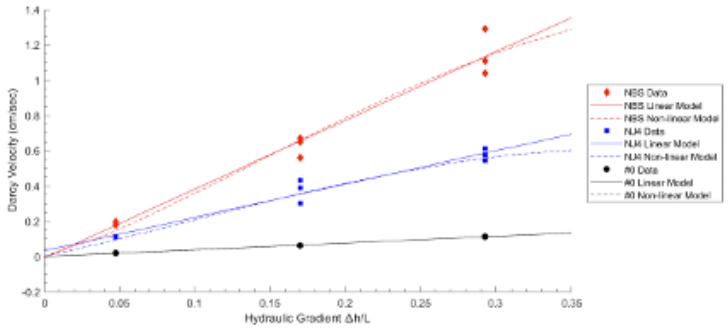

Figure 1. Darcy velocity (q) versus the hydraulic gradient (-dh/dL). This graph shows all the sands that do not follow Darcy's Law. The equations for the lines of best fits for both models can be found in Appendix A.

Commented : Fonts and symbols on graph could be made larger to facilitate readability.

Commented : The nonlinear models specified in the appendix are not correct and therefore this graph is wrong. Need to fit equation (8) to the data. This is a second order polynomial.

Figure S2. Instructor's comments on student reports aligned with the checklist; relevant instructions are highlighted in blue. Identifiable information anonymized.

Table S1. Grading rubrics (in blue); Instructors comments and grades on a draft report submission

Report element	Criteria	Points on the draft Report	Comment draft (See comments in document as well).
Title page (1 pt)	Title page contains all required information	1	Include date submitted.
Abstract (4 pts)	Abstract 300 words or less; Abstract addresses all points contained in the report writing guidelines.	3	Can include numerical results in abstract. See comments in text.
Introduction (15 pts)	1-1.5 pages; describes the problem being studied and relevant theory; instruction and theory in own words.	10	Well written but some items missing. See comments in document.
Materials and Methods (10 pts)	Experimental steps written in sentence form; Would another student be able to conduct the experiment by reading the M/M?	5	Incorrect format. Items are missing. Another student would not be able to conduct the experiment reading this section. Need to re-write in declarative/narrative form. See comments in document.
Results (25 pts)	3-4 pages; tables/figures/pictures presented sequentially and introduced in the text before discussed; tables/figures/pictures discussed thoroughly; proper statistical analysis used; sample calculations presented in the appendices	18	Results should be discussed in narrative form in the text rather than only presenting tables and figures. The narrative can then reference the figures and tables. Hazen results are missing from this section. The nonlinear model applied to the data as specified in the appendix is incorrect - Figure 1 therefore presents incorrect results. Need to calculate nonlienar model correctly. See comments in document. Good sample calculations in Appendix. Should include all Hazen graphs in appendices.
Discussion (25 pts)	3-4 pages; results discussed in terms of relevant theory and significance; experimental errors identified and discussed	12	0.5 pages of discussion narrative. Results are presented in a table but not discussed in narrative form. Need to fix. The MTBE problem can be presented in the appendix or a subsection; it is not relevant to the discussion of the lab results. Hazen is presented here but should be introduced in the intro.
Conclusion (3 pts)	0.5-0.75 pages; clearly and concisely state what was learned and its importance	2	Conclusion is missing some items. See comments in text.
References and Appendices (2 points)	Citations in text match references; sample calculations listed in appendices; data in appendices needed and are the data referenced in the body of the report	1	References include some items not cited in text. Dates missing from 2 citations that can easily be found.
Report Layout (5 pts)	sections and subsections labeled correctly; margins 1" around; Times New Roman 12 font; included page numbers; figures/tables/images presented at the end of the text; tables/figures/pictures have descriptive headings	4	Page numbers are missing
Figures, Tables and Images (10 points)	Axes labeled and correct units presented; data symbols large enough and STD bars presented (if appropriate); Am I using the correct lines (point to point if no model/regression analysis used); legends needed and if yes are they appropriate if printed in black and white; Can tables/figures/images be combined to make it easier for the reader to assess results?	9	Fonts and symbols on graph could be made larger to facilitate readability.
Practical design problem (5 pts)	Straightforward calculations presented and interpreted	5	Correct answer. Better to offset in a separate subsection.
Total = 105 pts		71	0.67 Fraction of 105 points