2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #51210

Beyond the Rubric: How Checklists Changed Students' Writing Practice in a Chemical Engineering Lab

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ABSTRACT

Laboratory report writing is a core learning outcome in chemical engineering, yet as instructors we routinely see the same problems: missing content, weak analysis, and large variation in quality despite the use of detailed instructions and grading rubrics. This paper reports on the introduction of a structured laboratory report checklist in an upper-level chemical engineering laboratory course and examines how it changed student writing practices, instructor workload, and assessment consistency over multiple semesters. Using student surveys, reflections, and instructor-evaluated scores, we show that the checklist improved report completeness, supported student self-regulation, reduced grading variability, and promoted more equitable outcomes by making expectations explicit. The checklist may also have helped in a writing environment where students used AI for report writing, guiding them to use generative tools without giving up their own analytical work. Together, the results suggest that simple, well-designed checklists can function as powerful, low-effort teaching tools in laboratory courses.

1.0 INTRODUCTION

Anyone who has graded laboratory reports knows the pattern, even strong students miss required components, misinterpret what counts as appropriate analysis and discussion, or submit work that feels rushed and uneven. This happens not because students lack ability, but because laboratory writing is a complex task with many moving parts that must come together under time pressure.

In *The Checklist Manifesto*, Atul Gawande makes a point that resonates strongly with engineering educators: in complex systems, failure usually comes from skipped steps rather than missing knowledge [1]. That is why fields such as aviation, surgery, and construction rely on checklists even when highly trained professionals are in charge. A checklist does not replace expertise, rather it makes sure that expertise is applied systematically and reliably [2].

Over 8000 bachelor's degrees awarded annually in chemical engineering in the US and all the programs typically require students to complete at least one formal technical reports [3,4]. In engineering laboratory courses, students design experiments, analyze data, and communicate results using disciplinary conventions that may be often conveyed as partially explicit to them [5-7]. Although most instructors use rubrics to grade reports, rubrics primarily tell students how points are allocated after the work is submitted. They do not always guide students while they are writing [8-9].

This gap matters, especially in diverse classrooms. Students who are first-generation, multilingual, or new to scientific writing may not have internalized the hidden rules of what a "good" discussion section looks like. When expectations are implicit, some students guess correctly and others do not. The result is not just uneven writing but uneven opportunity. In addition, study suggests excessive instructor intervention at every stage of writing can unintentionally limit students' development of independence and self-regulation [10]. Structured checklists offer a complementary approach [11]. Unlike rubrics, which are evaluative, checklists function as formative writing tools that students can actively use while drafting and revising reports. A checklist provides a shared reference for what is expected, supports self-assessment, and allows instructors to focus feedback on higher-level reasoning rather than missing components. Importantly, checklists also align with principles of inclusive teaching. By making expectations explicit and reducing reliance on unspoken norms, checklists can support students from diverse educational and linguistic backgrounds who may be less familiar with the conventions of scientific writing.

This study investigates whether structured laboratory report checklists can improve student writing practices, instructor-evaluated performance, and equity in assessment within a chemical engineering laboratory course. Specifically, the study examines how students use checklists, how instructors evaluate student performance before and after checklist implementation, and how checklists interact with emerging practices such as large language model (LLM) assisted writing.

2.0 METHODS

2.1 Study Design

The study was conducted in an upper-level undergraduate chemical engineering laboratory course in an R1 university in the mid-Atlantic region of the US. The course is a regular offering only in the fall semester. Intervention data was collected in two years: Year1; n = 24 and Year 2; n = 32. Students completed multiple laboratory experiments and submitted formal technical reports following disciplinary conventions. Instructor-evaluated performance from the year when no checklist was used, served as a comparison baseline.

To better understand students' study habits and how they approach laboratory report writing, first a pre-lab survey was administered at the beginning of the course in 2025 semester.
The survey instrument was developed based on prior literature on student self-efficacy, study behaviors, and engagement in laboratory and writing contexts [12-13]. Items were designed to capture students' report-writing practices (e.g., initiation, organization strategies), perceived difficulty across report sections, and self-reported confidence. Participation in the surveys was voluntary and did not affect course grades. Responses were collected anonymously. Two sets of survey data were analyzed: a pre-lab survey focused on students' baseline writing habits and perceptions, and a post-intervention survey examining students' experiences with a structured laboratory report checklist and their use of large language models (LLMs) during the course.

The study followed a mixed-methods descriptive design. Quantitative survey items were used to capture trends in students' writing behaviors, confidence levels, checklist usage, and perceptions of usefulness. Open-ended survey responses were used to provide qualitative context, particularly regarding challenges in laboratory writing and student perceptions of checklist clarity. The purpose of the surveys was not to measure learning gains directly, but to characterize student practices and perceptions before and after the introduction of the checklist, thereby informing interpretation of checklist effectiveness. Institutional review and approval will be pursued in accordance with university policies as the study moves forward.

2.2 Checklist Intervention

A structured laboratory report checklist was first introduced in Year 1 and revised in Year 2 based on instructor experience and student feedback. The checklist outlined required components for each report section (e.g., Abstract, Introduction, Methods, Results, Discussion) and emphasized content inclusion rather than grading weights. Students were encouraged to reference the checklist throughout the writing process and to use it as a self-check tool prior to submission. The checklist supplemented, rather than replaced, rubrics and instructor feedback. A section of the sample checklist is shown in the Supplementary Information. The checklist was developed using the following guiding principles:

- **Guiding prompts or examples when helpful:** For some items, we included a brief prompt or example. For instance, for the Discussion section an item might be "what trend your results show? Discuss the trend with possible scientific mechanism e.g., lower absorption was observed due to electronic structure of molecule A vs B."
- **Visual clarity and checkbox format:** The checklist was formatted with clear headings, whitespace, and actual checkboxes for each item. Students were required to fill it out with a check mark, and indicate the page number it was in. The checkbox format reinforced that this is a working document to actively engage with, not just a piece of text to read.
- **Designed for self-assessment:** We explicitly told students to use the checklist to self-evaluate. In fact, there was a column where they could tick "Yes/No" for whether they addressed each item. This turned the checklist into a simple rubric *for themselves* before submission.
- Lastly, alignment with course learning objectives and grading rubrics were carefully checked for the checklists.

2.3 Data Analysis

Two open-ended laboratory experiments were selected for detailed analysis. Students submitted draft reports, received written feedback, and revised as needed. Instructor-evaluated scores across three years were summarized in the Results and Discussion section.

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.

3.0 RESULTS AND DISCUSSION

3.1 Baseline Writing Habits and Challenges

Before introducing the checklist, we wanted to understand our students' starting point. The pre-course survey revealed some clear patterns in how students approached lab report writing. A majority of students reported that they waited until shortly before the deadline to start writing their lab reports, rather than beginning soon after the experiment was completed. It was common for students to procrastinate and then write under time pressure, which likely contributed to errors or omissions in their work. When asked how they usually begin writing a report, responses were quite varied and often unstructured. Very few students said they start by making an outline or plan; most tended to just start writing from the beginning or compile bits of content without a strategy. This suggests many students lacked a deliberate writing process.

Students also identified which part of a lab report they found most challenging. By far the most frequently cited was the *Discussion section*, where they have to interpret results and connect back to theory. Qualitative comments highlighted why: some felt unsure about how deep their analysis should go, some struggled with explaining unexpected results, and others were not confident about how to structure a coherent argument about what the data meant. Another pain point that emerged was simply *knowing what is expected* in each section. When asked if they understood what content should go into each part of the report (Introduction vs. Results vs. Discussion, etc.), a number of them selected neutral or even disagree on understanding these expectations. In summary, the baseline survey painted a picture of students who often delay writing, lack a structured approach when they do start, and feel the most difficulty in the analytical portions of the report. These are exactly the kinds of issues a checklist might help address by breaking the task into clearer steps.

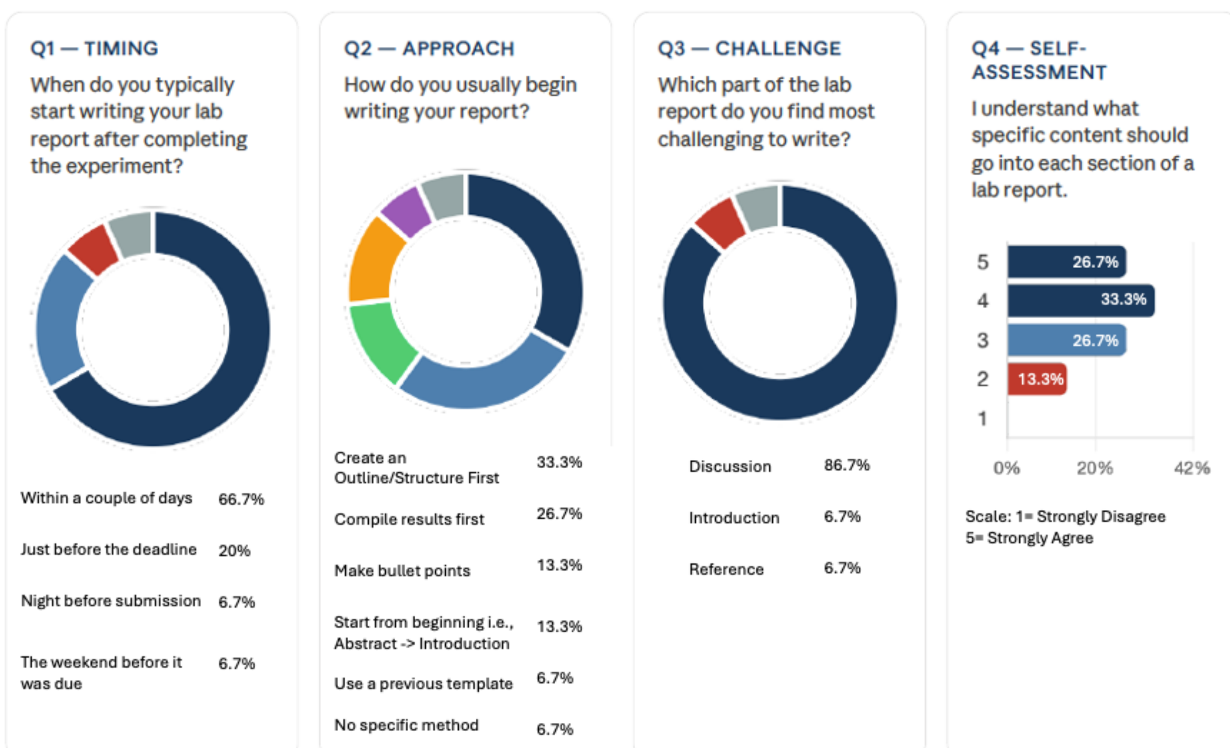

Figure 1. Baseline survey of student lab report writing habits (n=31). While writing strategies and start times vary across the cohort, a significant majority (86.7%) identify the Discussion section as the most challenging to write.

3.2 Checklist Use and its Perceived Impact

After introducing the structured laboratory report checklist, survey responses showed strong levels of active use and positive perceptions among students. As shown in Figure 2, a large majority reported referring to the checklist throughout their writing process rather than only at the final stage, indicating that students treated it as a real working tool rather than a post-hoc checklist. When asked about its usefulness, most students commented that the checklist helped them include required content, better organize their reports, and clarify expectations for each section. These positive responses were consistent across multiple survey items designed to capture different dimensions of perceived usefulness. In addition, an overwhelming proportion of students (93.3%) expressed a clear preference for having similar checklists available in future laboratory courses, suggesting that they found the intervention beneficial enough to support broader adoption. These descriptive findings, summarized with frequencies and percentages, provide evidence that the checklist was both used and valued by students in ways that align with its intended purpose.

Beyond the raw usage and preference data, we wanted to know *how* the checklist affected students' approach to writing. The survey and student comments suggest that the checklist encouraged beneficial self-regulation habits. Instead of relying on an instructor or TA to catch omissions or remind them of sections, students were taking ownership of those tasks. **90.3%** of students said that while preparing their lab report, they *actively checked the checklist item-by-item as they wrote each section*. Only a couple of students said they used it solely at the end for a final review, and virtually none reported ignoring it. This means the checklist introduced a new behavior: students iteratively verifying their work against an external guide, which is a form of self-monitoring. Importantly, student suggestions for improvement such as clearer wording for certain items, better alignment with instructor feedback, and including the checklist with lab handouts should not be read as resistance. Rather, they show active engagement with the tool and a desire to refine it so it better serves their needs. In light of prior research warning against over-scaffolding, these findings suggest that well-designed checklists can strike a balance: they offer structure without substituting for students' own cognitive work, helping learners internalize expectations while maintaining responsibility for their writing [14].

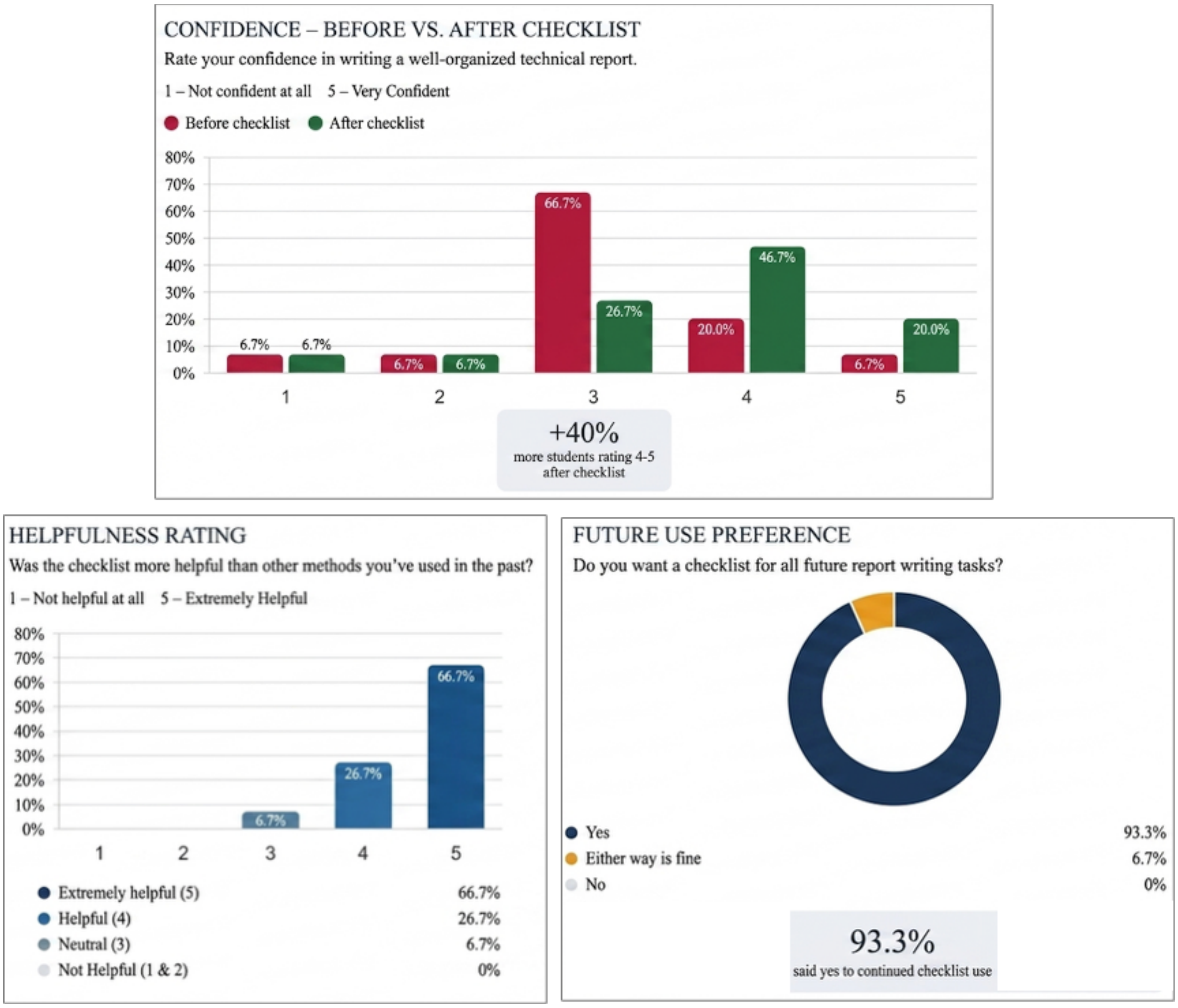

Figure 2. Survey data of students' perceived usefulness of the checklist in report writing (n = 31/32). **Top:** Self-reported confidence in writing a well-organized report improved after using the checklist (green bars) compared to before (orange bars). **Bottom Left:** 66.7% rated the checklist extremely helpful (5) and an additional 26.7% gave it a 4. **Bottom Right:** 93.3% of students want a checklist for all future report writing tasks.

3.3 Checklist Use in the Context of AI

Survey data (Figure 3) from this study indicate that approximately 50% students used large language models (LLMs) like ChatGPT throughout the laboratory report writing process, with usage reported at multiple stages including idea generation, grammar refinement, and checking completeness before submission. These patterns mirror findings from recent educational research: a survey of 539 engineering students across 12 universities found that over 40 % of learners used LLM tools regularly, with a strong focus on writing refinement and planning support rather than technical problem solving [15].

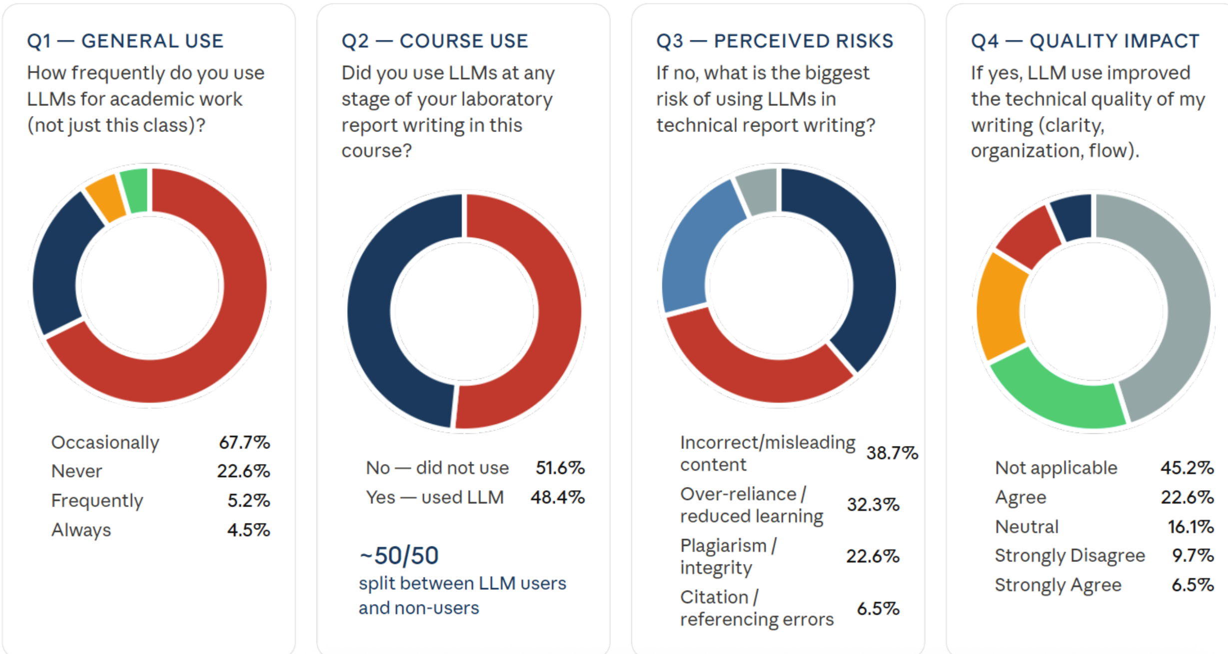

Figure 3. Survey data on use of LLM in report writing (n = 31/32).

In alignment with broader patterns of student use, our respondents described LLMs as helpful for brainstorming and surface-level editing, which aligns with findings in the literature that students often use AI tools to improve readability and grammar rather than for deep content creation [16]. However, survey responses also captured concern about over-reliance on AI, particularly the risk that extensive use could diminish students' own writing effort or critical engagement with technical content, a theme echoed in recent syntheses of AI in academic writing that identify over-reliance and reduced critical thinking as key challenges when students use generative tools without structured guidance [17]. A study of 401 U.S. university students showed that ethical beliefs about AI use strongly predicted how students approached AI-assisted writing, with many learners recognizing the need to balance convenience with maintaining academic integrity and cognitive engagement [18].

The increasing availability and use of AI tools introduces additional complexity in interpreting student writing outcomes. While approximately half of the students reported using AI for brainstorming or outlining, we did not rely on automated detection tools due to their known limitations. Instead, we interpret our findings as reflecting a learning environment in which students may use *AI as a support tool*. Importantly, the checklist appears to provide structure that guides students' analytical thinking, regardless of AI use. Future work should explore more direct measures of AI interaction, such as draft evolution or writing process data.

3.4 Diversity, Equity, and Inclusion (DEI) Aspect: Checklists was Equitable for Every Students

This section is primarily on anecdotal evidence; however, students feedback suggests that integrating structured checklists into writing instruction also promoted more equitable outcomes for students from diverse backgrounds in the course. Language barriers and varying educational backgrounds can cause some students to miss subtle cues in a rubric or assignment prompt. For example, a rubric might use terms like "analysis is nuanced" or "discussion is comprehensive." Such language can be *vague or intimidating*, potentially forming a barrier for students or first-gen students who feel unsure about academic jargon. A checklist, in contrast, tends to use very direct language: e.g., "Discuss any unexpected results and possible sources of error" is a clear directive that any student can attempt to follow. A checklist centers the assessment on objective criteria e.g., Was the hypothesis stated? Was a graph of X vs Y included with proper labels? etc. and thus can mitigate the risk of bias. Another DEI-related key advantage of checklists is their role in fostering autonomy and empowerment. Instead of being passive recipients of feedback, students actively use the checklist to self-evaluate which transfers some agency to the student [10].

3.4 Impact on Student Performance

Ultimately, did the checklist actually improve the quality of the lab reports as reflected in grades? While this was not a controlled experiment, the comparison of instructor scores before and after the checklist's introduction is encouraging. As illustrated in **Figure 4**, the 2023 class (which did not have a checklist) had a lower median score on the two major reports, and the variation in scores was quite large. Some students did very well, but many were scattered lower, including a few who clearly struggled a lot (e.g., outliers at the low end). When the checklist was introduced in 2024, the median score moved upward and the spread of scores narrowed. More students were meeting a higher standard, and fewer were falling through the cracks. By 2025, after we refined the checklist based on feedback, the median performance was higher again, and most students clustered in a high-performing range with almost no one at the bottom.

From an instructor's perspective, this progression was noticeable in grading. In 2023, we often saw missing pieces (e.g., a student forgetting to include an abstract or failing to comment on an obvious trend in the data). In 2024, such omissions were far rarer – the reports were more complete and uniform in covering required content. In 2025, the reports not only checked all the basic boxes but tended to be more polished; with the fundamentals ensured by the checklist, students appeared to invest more effort in fine-tuning their explanations and analysis. One could argue that the groups of students might have had differences in ability, but there wasn't any indication that the cohorts were significantly different academically (test scores and other course components were fairly similar across those years). The more plausible explanation we see is that the **checklist raised the baseline** of performance. Students who might otherwise have turned in incomplete or poorly organized reports were guided to produce something better, and the class as a whole benefited.

These observed gains align with well-established findings in educational literature on scaffolding, checklists, and transparent assignment design. The checklists functioned as a form of instructional scaffolding, breaking the assignment into clear, manageable components. A checklist also serves as a metacognitive tool: it helps students plan, monitor, and evaluate their progress on the assignment, thereby building organizational skills and keeping them on track, as observed by other researchers [19, 20].

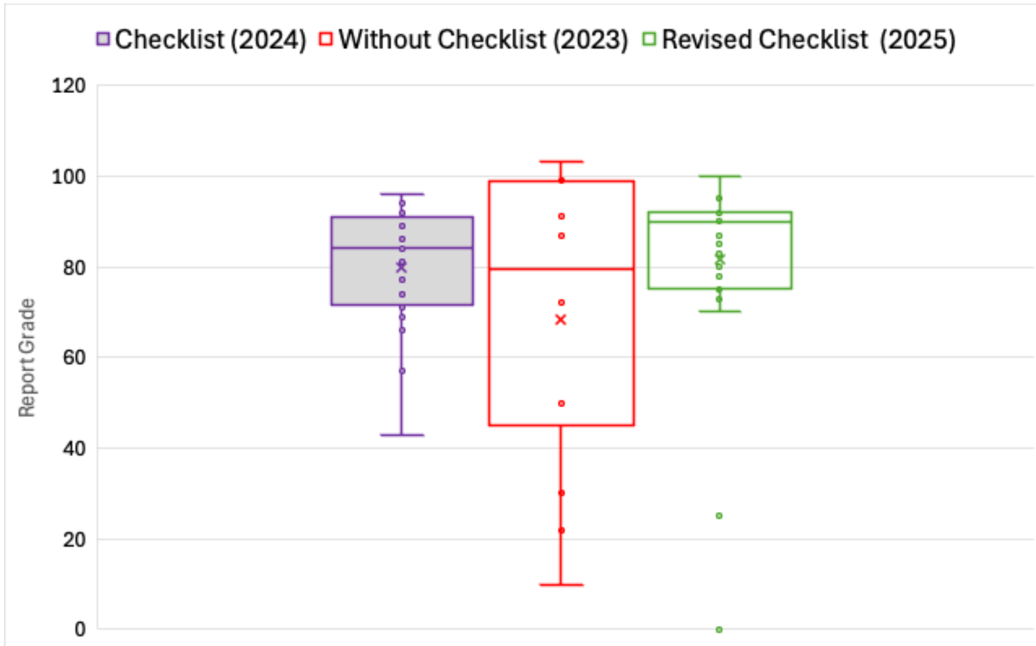

Figure 4. Instructor-evaluated report scores of the study groups (24 -25) vs a control group (23) shows the upward trend of the performance.

4.0 CONCLUSION

Structured laboratory report checklists improved student writing quality, instructor-evaluated performance, and consistency in assessment across multiple semesters. By making expectations explicit, checklists supported self-regulation, appropriate AI use, and equitable outcomes without lowering standards.

This study also suggests that checklists can standardize expectations without replacing feedback, support scalable writing instruction, and improve grading consistency. They are particularly well suited to AI-rich learning environments, where students benefit from clear guidance on where cognitive effort matters the most. For instructors facing large enrollments and limited feedback time, checklists offer a quick fix or a practical and inclusive instructional tool.

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SUPPLEMENTARY INFORMATION

Students are required to complete the checklist provided for the laboratory report to support organization, completeness, and clarity of their submission.

Instruction

- Indicate completion of each item by marking an "X" in the corresponding box to confirm that the element is addressed in the report.
- Reports will not be evaluated unless the checklist is completed and included with the submission.
- Students are encouraged to note the page number where each item is addressed; if an item is not applicable or not included, a brief explanation should be provided in the comments column.
- The completed checklist must be attached as the first page of the submitted report.

	Yes	No	Proof (Page/Section)
Title Page (2 points)			
☐ Separate title page (not counted in page limit). ☐ Includes descriptive report title. ☐ Includes my name, group members' names, date of lab, and report version (first/final). ☐ Includes institutional affiliation (UMBC, Department of Chemical, Biochemical & Environmental Engineering).			
Abstract (~ 300 words) (10 points)			
☐ States purpose of experiment and research problem (e.g., drug delivery context). ☐ Summarizes methods in 1-2 sentences. ☐ Summarizes key findings and/or numerical results (e.g., optimal design and its release rate or model parameters). ☐ Interprets results (meaning/significance) and covers overall conclusion in 1-2 sentences. ☐ Covers overall conclusion in 1–2 sentences. Comments (if any):			