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WIP: From Launch Data to Design Decisions: Assessing How Technical Memos and AI Tools Enhanced Engineering Reasoning in a First-Year Course

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WIP: Technical Memos, AI, and Design Reasoning in a First-Year Course

Introduction

This evidence-based practice Work-in-Progress paper reports on the redesign and preliminary assessment of a U.S. institution first-year engineering course that integrates analysis, design, and technical writing to strengthen students' evidence-based engineering reasoning and professional communication, including responsible use of AI-assisted writing tools. The redesign examines how students justify design decisions using mathematical models and empirical data in a one-page technical memo.

Although first-year engineering courses routinely include mathematical analysis, experimentation, and design projects, novices often experience these activities as disconnected tasks rather than as a coherent reasoning process that supports justified engineering decisions. Prior research demonstrates that engineering design reasoning is developmental and requires explicit instructional support to integrate evidence, evaluate alternatives, and justify decisions [1,2]. As a result, many students can compute results or build prototypes but struggle to explain how models, data, and constraints inform design choices, particularly in professional communication contexts. Technical writing plays a critical role in making such reasoning explicit, yet it is often treated as a reporting task rather than as a reasoning-centered activity. These challenges are further complicated by the increasing availability of generative AI tools, which can produce polished text without necessarily reflecting authentic reasoning.

This project redesigns a first-year engineering design course around an explicit evidence-to-decision framework. Students complete an iterative design challenge culminating in a one-page technical memo with aligned instruction, reflection, assessment, and guidance on responsible AI use. This Work-in-Progress reports preliminary patterns from aggregated rubric-based comparisons of memos from a baseline and redesigned offering, without isolating the effects of AI use, which are the focus of ongoing work.

Research questions:

1. How do first-year students integrate mathematical models, empirical data, and design constraints in technical memos?
2. What differences are observed in the quality of evidence-based reasoning and technical communication between offerings?
3. How is responsible use of AI-assisted writing tools incorporated into a first-year design reasoning intervention?

Methods

Course Context and Instructional Conditions

This study draws on student work from a first-year engineering fundamentals course in which student teams complete a five-week Projectile Launcher Challenge. Teams design, build, test, and refine a launcher to achieve a target distance under specified constraints, engaging in core engineering practices including problem definition, modeling and analysis, experimentation, and iteration. In both offerings, the project culminated in a one-page team technical memo addressed to a professional audience, requiring students to describe their design process, report performance, and reflect on lessons learned.

Two offerings of the course taught by the same instructor were compared. In Fall 2024 (baseline; $n \approx 40$ students, 10 teams), the project emphasized artifact completion and reporting of results, with limited explicit instruction on evidence-to-decision reasoning and no formal guidance on AI-assisted writing. In Fall 2025 (redesign; $n \approx 78$ students, 20 teams), the course was redesigned to foreground evidence-to-decision reasoning through structured problem-solving activities (e.g., design reviews), guided reflection aligned with the memo, and explicit instruction on using mathematical models and empirical data to justify design decisions. Students also received guidance on responsible use of AI-assisted writing tools. To reduce instructional variability, only sections taught and graded by the same instructor in both offerings were included in the analysis. While the course under question underwent significant redevelopment, the core aim related to this advancement in technical writing is the alignment and clarity among experienced engineering material, guidance on technical writing, and assessment of the two.

Assessment and Analysis

The aggregate data source for this study is students' final technical memos (Appendices 1 & 3). Memos were assessed using course-specific rubrics aligned with the launcher project in each offering. The Fall 2024 rubric (Appendix 2) emphasized documentation completeness, artifact inclusion, and reporting of results, whereas the Fall 2025 rubric (Appendix 4) emphasized articulation of the design process, comparison of predicted and measured performance, and reflective discussion. Although the rubrics differ in structure, both assess common constructs related to engineering reasoning in writing. For cross-offering comparison, criteria were aligned at the construct level, focusing on problem framing, design process articulation, use of evidence to evaluate performance, and reflection; total scores were not compared.

Memos were scored using the rubrics associated with their respective offerings, and performance levels were categorized using the levels defined in each rubric (e.g., Excellent/Good/Satisfactory/Poor in 2024; Excellent/Proficient/Needs Improvement in 2025). To support consistency in interpretation, the instructor reviewed a subset of memos from each offering to calibrate scoring decisions against rubric descriptors. High level descriptive statistics and effective size were calculated to compare the cohorts.

Results

Summative performance of the cohorts show Fall 2025 ($M=81\%$, $SD=14\%$) generally performed better than Fall 2024 ($M=50\%$, $SD=18\%$) with a very large effect size ($d=1.96$). Figure 1 presents the percentage of team technical memos from the Fall 2024 baseline and Fall 2025 redesign that were rated at the highest performance levels across four memo sections aligned with the engineering design process: Introduction (problem framing), Methods (design process and tools), Results (evaluation of performance), and Discussion (reflection and learning).

Across all four categories, a greater proportion of teams in the redesigned offering demonstrated high-level performance compared to the baseline. The most pronounced difference appears in the *Methods* section, where the percentage of high-performing teams increased substantially from Fall 2024 to Fall 2025. This shift suggests that the redesigned instructional emphasis on explicitly connecting mathematical models, engineering tools, and design decisions corresponded with clearer articulation of the design process in student writing. In the baseline offering, Methods sections more frequently emphasized procedural description or artifact reporting, whereas in the redesigned offering, teams more consistently described how analytical tools and design choices were connected.

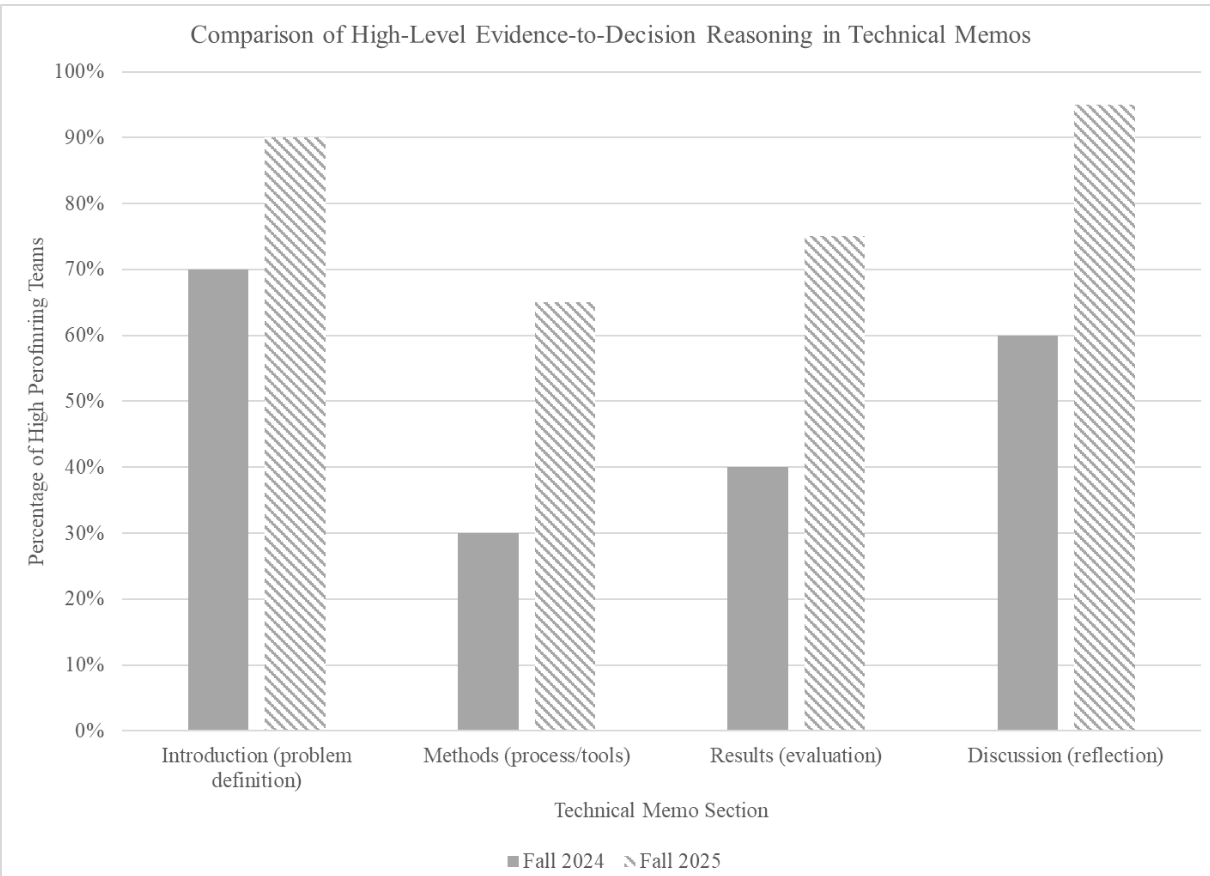

Figure 1: Percentage of team technical memos rated at the highest performance levels (Excellent/Good in Fall 2024; Excellent/Proficient in Fall 2025) across four memo sections aligned with the engineering design process. (Fall 2024: n=10 teams; Fall 2025: n=20 teams)

Improvements were also observed in the *Results* section, where a larger share of teams in the redesigned offering clearly compared measured launcher performance to analytical predictions. In contrast, baseline memos more often reported experimental outcomes without interpretation or comparison to expected performance. The *Discussion* section shows a high proportion of strong performance in both offerings, with a modest increase in the redesigned course. This pattern suggests that while students were generally able to reflect on outcomes and teamwork, the redesigned approach may have supported more technically grounded reflection. Differences in the *Introduction* section were comparatively smaller, indicating that problem framing may be less sensitive to the instructional changes implemented or already well supported in both offerings.

Taken together, these preliminary results suggest that aligning instruction, assessment, and memo-based communication around evidence-to-decision reasoning corresponds with observable shifts in how students articulate design decisions in writing. Since these findings are based on aggregated descriptive comparisons from a single instructor's sections, no causal claims are made; rather, the results highlight patterns that motivate continued investigation and refinement of the instructional and assessment approach. This example illustrates how analytical predictions, empirical testing, and design decisions were explicitly connected in student writing.

Excel is used to analyze results from 15 projectile trials. The unique approach for this group is calculating the launch angle of each trial from the inverse tangent angle. The Excel average function was used to find an average initial velocity and height. This data was used to evaluate the best launch angle for the launcher using Goal Seek…….Applying physics concepts and Excel strengthens the value of the data and predicting performance, and improving design reliability.

Discussion and Future Work

The preliminary patterns reported here suggest that aligning instruction, reflection, assessment, and memo-based communication around an evidence-to-decision framework may support stronger articulation of engineering design reasoning in first-year student writing. The largest gains observed in the *Methods* and *Results* sections align with the redesigned emphasis on explicitly connecting mathematical models, empirical data, and design decisions, consistent with prior research showing that novice designers benefit from structured support when integrating analysis and experimentation into coherent decision justification. Smaller differences observed in problem framing and reflective discussion suggest that some phases of the design process may already be well supported, while others may require additional scaffolding to deepen technical interpretation rather than descriptive commentary.

This work has several limitations. The analysis is descriptive, focuses on aggregated team-level outcomes, and is limited to sections taught by a single instructor. Differences in rubric structure across offerings required construct-level alignment rather than direct score comparison, and formal inter-rater reliability statistics were not calculated. Technical memos were submitted by teams with inconsistent evidence of collaborative writing, so these findings may not represent development of individual students. Additionally, guidance on responsible AI use was introduced as part of a broader redesign, preventing isolation of its individual effects. Future work will examine these trends using additional cohorts and formal IRB-approved analysis. Specifically, future work will include score student work on a content validated rubric on evidence-based design reasoning rather than technical writing capacity and a survey scale that relates AI usage across the engineering design process that structured the course. Additionally, purposeful sampling for semi-structured interviews could enhance interpretation of rubric scores. Finally, future work around design reasoning will need to be grounded in a formal framework.

References

[1] Atman, C. J., et al. (2007). *Engineering design processes: A comparison of students and expert practitioners*.

[2] Crismond, D. P., & Adams, R. S. (2012). *The informed design teaching and learning matrix*.

[3] Cross, N. (2004). *Expertise in design: An overview*.

[4] Dym, C. L., et al. (2005). *Engineering design thinking, teaching, and learning*.

Appendix 1. Fall 2024 Assignment Description

Launcher Project Technical Memo

To: Instructors Name

From: Team member 1, Team member 2, Team member 3, Team member 4

Date: Insert the date of the memo

Note: The purpose of the technical memo is to clearly and concisely explain your concept generation and selection process and how well your device performed as demonstrated through your testing so that the reader (e.g., your instructor):

- can understand the concepts you considered;
- can understand and follow your concept selection process;
- can confirm that you understand the problem; and
- can clearly understand how your team performed relative to the cost and performance metrics.

Introduction: (Identify your purpose for writing the memo. Answer the questions: what did you do, why did you do it?)

Provide a statement or two that summarizes the scope of why you worked on the project, the goals/objectives of the project, and what were the expected outcomes. Think beyond the obvious stated objectives in the overview document.

Methods: (Answer the question: How did you do what you said you were going to do in the introduction)

Provide a statement or two that summarizes how you achieved the goals/objectives of the project (e.g., discuss the design process "The engineering design process was implemented to formulate a solution to the project discussed in the introduction. This process consisted of ….”). Be sure to clearly and concisely identify how the engineering design process was used. Make sure to highlight the use of the engineering tools and methodologies that allowed your group to reach the project solution created. Including your concept generation, concept selection, solid model (and drawings), and BOM in the Appendix section.

Summary of Results: (Organize and present your results. This section is used to describe the results of application of the methods you discussed in the previous section.)

Provide a summary of the results of your implementation of the design process. Include an objective evaluation of your device's actual performance based on testing and observation. Data tables of preliminary, final, and demo day results should be in the Appendix section.

Conclusion: **(Close by summarizing your interpretation of the results)**

Provide a summary of what was learned from working as part of this project team. Include a focus on the technical and also the non-technical aspects (e.g., time management and teamwork.)

Do not write in First Person.

Note: (These four sections make up the one-page written portion of the Tech Memo. Any addition figures, tables, etc. belong in the Appendix and that section can be as many pages as required.)

Be sure to remove all of the notes / guidelines in Blue before you submit your memo!

Appendix: **(Used to add supplemental detail to the one-page written report)**

Include any and all information that you are discussing in the Introduction, Methods, and Summary sections of the report. This should include the following:

- All Concept Sketches
- Completed Decision Matrix
- Initial Engineering Design (3D Model, 2D Drawing)
- Initial BOM with Cost
- Updated BOM to reflect the final design with Cost
- A Photo or Image of your final launcher design as built (Final Engineering Design)
- Completed Gantt Chart
- Launcher Calibration Data
- Demo Day Results

Make sure each Figure / Table has a proper title and is properly numbered. Reference anything included in this Appendix by the Figure or Table number when mentioned in the written portion of the Tech Memo.

References: **(If applicable)**

Include any references that were used in creation of this document.

NOTES: take advantage of Word's built-in citation tool. If you use this tool as you make your in-line citations, Word can generate that list here automatically for you. The two items below are simply an example.

[1] Dell's Wireless Charging Laptop. n.d. <http://www.pcmag.com/article2/0,2817,2353745,00.asp>.

[2] Solar Power Charging Station. n.d. 2011 <http://www.alibaba.com/product-

gs/410896584/14_5Wportable_PU_leather_Solar_Power.html>.

Appendix 2. Fall 2024 Rubric

Introduction	Excellent	Good	Satisfactory	Poor
	10 points	8 points	5 points	2 points
	Well-written. Clearly identifies the problem to be solved and defines success	Well-written. Vaguely identifies the scope of the project and the problem to be solved	Written in basic form. Vaguely identifies the scope of the problem to be solved.	Written in basic form. Does not identify the problem to be solved.
Methods	Excellent	Good	Satisfactory	Poor
	10 points	8 points	5 points	2 points
	Well-written. The entire design process is discussed. Including the use of various engineering tools.	Well-written. The entire design process is discussed. Limited discussion of various engineering tools.	Written in basic form. Vaguely discussed the design process. Discussion of tools is limited or missing. Does not reference projectile motion analysis.	Written in basic form. Does not discuss the entire design process.
Design Concepts	Excellent	Good	Satisfactory	Poor
	15 points	12 points	10 points	0 points
	All Concept Sketches are included and clearly documented with title and typed descriptions of operation. Final design is supported with a completed Decision Matrix that clearly highlights chosen concept and	Concept selection process is mostly documented. Includes Concept Sketches but lacks proper concept titles (e.g., not student name) or Decision Matrix included, but missing I and R ranking legend and/or	All Concept Sketches are included but lacking title or typed descriptions of operation. Final design is supported with a Decision Matrix but chosen concept not clearly identified and missing a legend for I and R scales.	Concept Sketches not included. Decision matrix not included.

	included a legend for I and R scales.	chosen concept not clearly identified.		
Project Engineering Solution	Excellent	Good	Satisfactory	Poor
	20 points	17 points	12 points	5 points
	Engineering Design included (3D model and 2D drawing) and engineering of design discussed in written text. Updated BOM included and is a complete parts list of final build.	Engineering Design included (3D model and 2D drawing) and engineering of design discussed in written text. BOM included but is not a complete parts list of final build.	Missing one of the parts of the Engineering Design: 3D model or 2D drawing. BOM included but is not a complete parts list of final build.	Final Engineering Design not included, but some discussion of engineering in written report. BOM not included.
Fabrication and Testing	Excellent	Good	Satisfactory	Poor
	20 points	17 points	12 points	5 points
	Clearly discusses how the device performed. Final device picture included. Required data is included and well organized. Data includes calibration results table and demo day results.	Lacks full discussion of how the device performed. Final device picture included. Required data is well organized. Calibration results table or demo day results included.	Lacks full discussion of how the device performed. Missing Calibration results table or demo day results or Final device picture.	Test results section is incomplete and lacks detail/discussion of performance.
Project Budget	Excellent	Good	Satisfactory	Poor
	5 points	3 points	1 points	0 points
	Budget details included, proposed/initial and final.	Budget details included, proposed/initial and final.	Budget details included, but missing initial or final.	Budget details missing
	Excellent	Good	Satisfactory	Poor

Conclusion & Lessons Learned	10 points	8 points	5 points	2 points
	Detailed review of all technical aspects of the project ("process of engineering", results, etc.) Lessons learned mentions interpersonal aspects of the project (team dynamics, scheduling, etc.)	Detailed review of technical aspects of the project. Missing lessons learned on interpersonal aspects of the project missing.	Detailed review of some technical aspects of the project ("process of engineering", results, etc.) Lessons learned on interpersonal aspects of the project missing.	Limited review of the project and lessons learned.
Appendix	Excellent	Good	Satisfactory	Poor
	10 points	7 points	5 points	2 points
	All figures are numbered & titled and all figures are referenced in written portion of memo.	Figures are not numbered or are not titled. Some figures not referenced in written portion.	Figures are not numbered and are not titled. No figures referenced in written portion.	Appendix is incomplete.
Overall technical writing style	Excellent	Good	Satisfactory	Poor
	10 points	8 points	5 points	2 points
	Grammar, spelling, punctuation, and capitalization are correct. Written in third person.	There fewer than 3 errors in grammar, etc. Written in third person.	There are 3 to 5 errors in grammar, etc.	Written in first person.

Appendix 3. Fall 2025 Assignment Description

Launcher Project Technical Memo

To: **Instructors Name**

From: **Team member 1, Team member 2, Team member 3, Team member 4**

Date: **Insert the date of the memo**

Directions: The purpose of the technical memo is to clearly and concisely explain your engineering design process and results for Project 1, <u>keeping it to a one-page memo.</u>

Introduction: (Identify your purpose for writing the memo. Answer the questions: what did you

do, why did you do it?)

Provide a few sentences that summarize the scope of why you worked on the project, the goals/objectives of the project, and what were the expected outcomes. Think beyond the obvious stated objectives in the overview document. These should be high-level objectives, not every specific detail of the project.

Methods: (Answer the question: How did you do what you said you were going to do in the Introduction)

Provide a few sentences summarizing how you achieved the goals/objectives of the project (e.g., discuss the design process). Be sure to clearly and concisely identify how the engineering design process was used to help guide your decisions. Make sure to highlight the use of the engineering tools and methodologies that allowed your group to reach the project solution created. Discuss your integration of physics, math, and Excel to predict launcher results and aid design decisions.

Summary of Results: (Organize and present your results. This section is used to describe the results of application of the methods you discussed in the previous section.)

Provide a summary of the results of your implementation of the project. Include an objective evaluation of your device's actual performance (accuracy and precision) based on testing and observation. How did your group do on Demo Day compared with your predictive analysis?

Discussion: (Close by summarizing your interpretation of the results)

Provide a summary of what was learned from working as part of this project team. Include a focus on the technical and non-technical aspects (e.g., time management and teamwork.)

Do not write in First Person.

Note: (These four sections make up the one-page written portion of the Tech Memo.

Be sure to remove all of the notes / guidelines in Blue before you submit your memo!

Appendix 4. Fall 2025 Rubric

Introduction	Excellent	Proficient	Needs Improvement
	2.1–3.0 points	1.1–2.0 points	0.0–1.0 points
	Well-written. Clearly identifies the problem to be solved and defines success	Well-written. Vaguely identifies the scope of the project and the problem to be solved	Written in basic form. Does not identify the problem to be solved.
Methods	Excellent	Proficient	Needs Improvement
	5–7 points	3–4 points	0–2 points
	Well-written. The entire design process is discussed. Including the use of various engineering tools.	Written in basic form. Vaguely discussed the design process. Discussion of tools is limited or missing. Does not reference projectile motion analysis.	Written in basic form. Does not discuss the entire design process.
Summary & Discussion	Excellent	Proficient	Needs Improvement
	4–5 points	2–3 points	0–1 points
Summary of Results	Well-written. Clearly compares the launcher performance to predicted values.	Well-written. Vaguely compares launcher performance to predicted values.	Written in basic form. Does not discuss how the launcher performed compared to analysis.
Discussion	Detailed review of technical aspects of the project. Lessons learned mentions interpersonal aspects of the project (team dynamics, scheduling, etc.).	Detailed review of technical aspects of the project. Missing lessons learned on interpersonal aspects of the project missing.	Limited review of the project and lessons learned.