GIFTS: Recreate: Experientially Motivating Professional Standards in Engineering Documentation

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This GIFT presents an activity for supporting early-career university students in experiencing the importance of professional documentation through a two-stage “recreate” challenge. This activity is highly adaptable and has been used in a variety of Design-Build courses; it can be easily adapted to other contexts in early engineering courses as well.

Motivation

Documentation is a critical component of an engineer’s toolbox. As engineers gain experience, the emphasis of learning shifts away from pure technical expertise and theoretical knowledge toward professional skills, systems thinking, and problem-solving [1]. In industry, practitioners spend 60% of their time on communication, using documentation as a reference, legal evidence, and the primary means of ensuring work is reproducible and auditable [2].

Unfortunately, students are often not exposed to the standards of industry-level engineering documentation until their capstone year; as such, we consistently observe that students struggle to fully grasp the expectations of professional documentation [3, 4]. In university courses, students often view documentation as a 'product-based' artifact for external evaluation rather than a 'process-based' resource for their own design work. Consequently, they treat notebooks as a dossier of finished work for a grade rather than a living record [4, 5]. A frequent byproduct of this perspective is that students document as if the reader is already an expert on the project, creating a significant barrier to comprehension, usability, and increasing the chance of reader error or misunderstandings as a whole [3].

While industry demands fully documented products for safety and commercial defensibility, students often undervalue the role that documentation plays within their own design process, perceiving it as secondary to the “real work” of engineering [2, 4, 5]. This mismatch in perspective creates a significant “preparedness gap,” where graduates encounter significant workplace challenges, specifically regarding the technical writing and communication skills required on the job [1]. From the industry perspective, practicing engineers believe that university projects often feel unrealistic as there are no real consequences for mistakes and poor documentation; thus, the requisite communication skills are best developed through simulation, case studies, and design projects that mimic real world stakes of professional practice [2].

As instructors of early engineering design courses [6, 7], we feel a responsibility to provide a strong foundational experience that makes these professional standards relevant, addressing the disconnect before it becomes a barrier to our students’ future success. This GIFT confronts students with the consequences of poor documentation in a collaborative and low stakes learning environment, in turn motivating learners to adopt professional standards.

Objectives

In practice, instructor observations across engineering courses reveal a persistent disconnect in student behavior: while students find notebooks useful during stages of early design ideation, they frequently abandon them during critical active-build stages in favor of "designing on the fly" [4, 5]. Recreate disrupts this habit by grounding students in a shared experience of the consequences of poor documentation. By the completion of Recreate, students are able to:

- **articulate why documentation is a critical component of engineering work**: moving beyond viewing notes as solely memory aids to recognizing records as epistemic objects for the reproducibility, auditability, and defensibility of engineering work.
- **identify and apply the characteristics of high-quality documentation**: transitioning from a "checklist" mindset to a rhetorical consciousness of professional standards where students understand the logic and purpose of documentation in industry work.
- **practice documentation conventions with greater intentionality in the production of artifacts**: transitioning from "designing on the fly" to maintaining a continuous, traceable record throughout the full design process, not just in notebooks but other forms of professional documentation as well.

The activity provides a structured, repeatable way to introduce professional documentation standards across early engineering design classes while having students participate in an experiential shared experience, satisfying requirements laid out in [1, 2, 8].

Implementation

The *Recreate* challenge is a lightweight, two-stage activity designed to run in a single 65-minute class session. Its implementation is rooted in the four main principles of Productive Failure (as defined in [8]): a pedagogical design which begins with the activation of students' prior knowledge, uses failure to identify a concept's key components (features), and provides formal explanations before students assemble the final target concept. To achieve this, *Recreate* activity uses an adaptable *carrier* - a simple task - used to ground complex professional standards. In our implementations, we have used two carrier artifacts depending on the time availability for the activity. For a more authentic design experience, we use the recreation of a spinning top design as the carrier, which necessarily takes more of the class time. For a less cognitive load and/or a shorter time block, students are tasked to recreate two different pieces of pixel art (See Figures 1, 6 in the Appendix for more information on these carriers).

Stage 1: Activation and Productive Failure (~40-50 minutes)

The first stage of the activity focuses on establishing concrete experience and productive failure, where students confront the limitations of their own documentation standards. The following is our implementation for a single class session:

1. **Prior Knowledge Activation:** The session begins with the activation of prior knowledge through a "Question of the Day" prompt/reflection followed by a short class discussion. We ask students to define the purpose of an engineering notebook and notebooks in general based on their past experience and exposure. This establishes a baseline of student expectations for notetaking before the task begins.
2. **Replication of Carrier**: Small groups of 3-4 students attempt to recreate a carrier artifact using intentionally flawed notes that, while meeting initial student expectations, contain critical logic gaps (see Figures 2, 7 in Appendix). Thus, when students attempt the task, they encounter logic gaps or other common notebook omissions, leading to difficulties that ultimately result in failure to accurately recreate the artifact (see Figure 3 for examples).

3. **Class Discussion & Debrief**: Immediately following the failure, the instructor leads a guided debrief where students share their specific points of frustration with the notes - articulating WHY they are frustrating. This facilitated discussion asks students to explain and elaborate on the features of good/bad notebooks, both in terms of organization and content; students identify exactly where and why the notes provided had failed them.
4. **Guide-Building:** As a class, Students then formulate these failures as guidelines or heuristics for a good notebook; we recommended it as a whiteboard activity. This step allows students to take ownership of the documentation standards set for the entirety of the class. This stage of the activity culminates with the introduction of self-documentation as the definitive standard for professional notes, where if an unrelated third party (the proxy) can understand and recreate the work, the author has guaranteed they themselves will be able to understand and use that work in the future.

By navigating this cycle of failure and reflection students move from a surface-level understanding of documentation to co-constructing a set of formal guidelines for their own work. This transition ensures they are not just following a list of rules, but are active participants in establishing the standards of their professional practice.

Stage 2: Success and Far Transfer (~15 minutes)
Student groups repeat the replication challenge, this time with another set of notes that better match the new standards set forward by both instructors and students (see Figures 4, 8 in Appendix). Armed with a new rhetorical consciousness, students expectedly complete this portion with more accuracy and significantly less friction, creating a memorable difference in contrast to the previous stage (see Figure 5 for an example). By regularly referring back to Recreate's output (the student-developed guidelines) throughout the course, this activity supports the ultimate goal of fostering *far transfer*: moving students towards applying these competencies to other contexts, whether that be writeups, white papers, or other forms of documentation.

Assessment

The impact of this activity is measured through a mixed-methods, pre-post design that is integrated into the classroom's *Question(s) of the Day* structure as well as the regular student notebook assignments. The 'Question of the Day' is asked at the beginning of each class to capture real-time understanding and ensure notebooks are active and accessible. Before the Recreate activity, these questions portray initial student conceptions regarding professional documentation while a follow up Question of the Day asked after the activity captures any change in perspective and retention of concepts. We analyze these responses for two key changes in mindset: 1) a conceptual shift in students' perspective from viewing documentation as a classroom product to a personal aid and a professional tool, and 2) an increase in their perceived value of documentation.

Quantitative Growth in Perceived Utility

Students across three unique implementations of the activity scored the importance of the engineering notebook on a scale of 1 (not useful) to 10 (super useful), providing pre- and post-activity ratings to reflect their shift in mindset. This approach allows students to contrast their prior assumptions with the realities experienced during the Recreate challenge. Responses indicate that prior to the activity, students rated the importance of engineering notebooks in a moderately high range (Mdn = 7, IQR = 1). Following the activity, ratings shifted upward (Mdn = 8, IQR = 2), suggesting a modest increase in perceived importance alongside greater variability in responses. This pattern is consistent with the possibility that the activity influenced students' perceptions of documentation, though the increased spread indicates that the effect was not uniform across participants.

Qualitative Evidence of Mindset Shift

Pre-post Questions of the Day asked learners, "What is an engineering notebook?" and "Why do you think engineers keep notebooks?" The follow-up Question is administered one week after the Recreate activity, additionally asking students to identify specific documentation features that aid in reproducibility and collaboration. These qualitative reflections provide a deeper look into how students internalized the professional standards covered in the activity. Responses indicate a significant shift in awareness of the target audience, specifically highlighting the needs of their peers and the continuity of a project. Multiple students noted that high-quality records ensure a project "*doesn't come to a halt*" if a member is absent and allows teammates to "*pick up where someone left off without having to ask for details again*." These realizations address the core of the mismatch by moving the student from a solely self-centric perspective to one that balances both the needs of themselves and those of an external stakeholder.

When asked, "What specific things make a notebook clearer for someone to be able to reproduce work?" students identified tangible and functional requirements, emphasizing the need for "*step by step detailed instructions*," "*visual diagrams*," and "*quantitative observations*" to promote reproducibility. Furthermore, students highlighted the importance of documenting not just the product and final successful outcome, but the process as well, such as "*what worked and what didn't*" and the "*intent behind actions*."

This level of detail indicates that students have begun to internalize the need for chronologically traceable, thorough records that are valid in professional environments. By identifying the need for specific, reproducible data, students recognize that documentation is a functional dependency of the technical design process. This intentionality ensures that the work remains defensible and auditable, meeting the professional standards that the industry demands.

Conclusions

In summary, this GIFT addresses the mismatch in perspective between students and professional engineers by replacing passive instruction with a shared experience of productive failure. By having students navigate a technical task where their existing habits are insufficient, the activity demonstrates the functional necessity of professional standards. Our assessment results indicate a meaningful shift in the student mindset, characterized by an increased valuation of technical records and an audience-centric understanding of thoroughness. Ultimately, this activity provides a scalable framework for the far transfer of these habits into high-stakes engineering and design environments, ensuring that future engineers adopt the habits necessary for long term professional success.

References

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Appendix A: Activity Materials for a longer implementation of Recreate

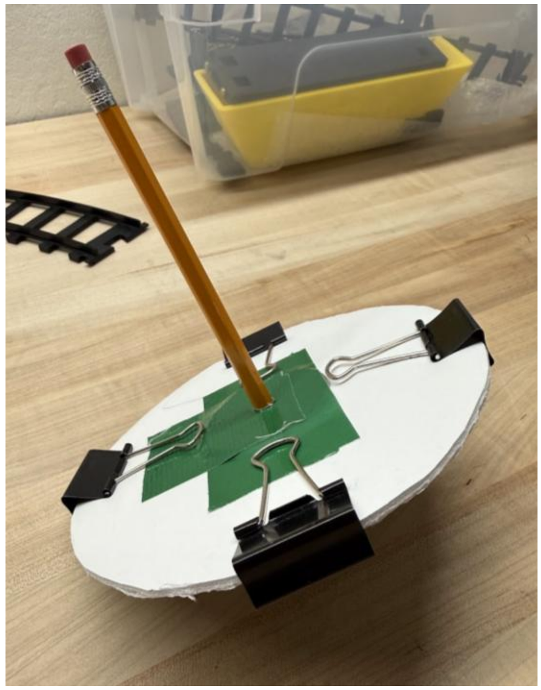
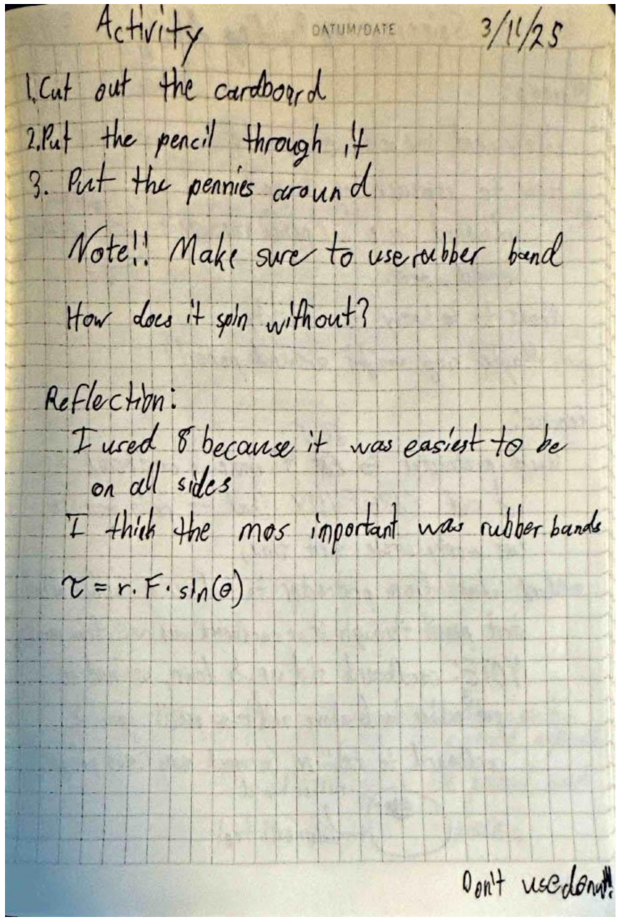


Figure 1: Example Carrier for a more design-authentic implementation of Recreate. *This artifact represents the completed design that students aim to recreate (a spinning top). While students are not shown this physical model during the activity, the "high-quality" documentation provided in Stage 2 is designed to lead them to this specific, functional outcome.*



Activity DATUM/DATE 3/11/25

1. Cut out the cardboard
2. Put the pencil through it
3. Put the pennies around

Note!! Make sure to use rubber band

How does it spin without?

Reflection:

I used 8 because it was easiest to be on all sides

I think the mos important was rubber bands

$\tau = r \cdot F \cdot sin(\theta)$

Don't use donut!

(a)

Activity 3/11/25

1. Cut out the cardboard
2. Put the pencil through it
3. Put the pennies around

Note!! Make sure to use rubber band
How does it spin without?

Reflection:
I used 8 because it was easiest to be on all sides
I think the mos important was rubber bands

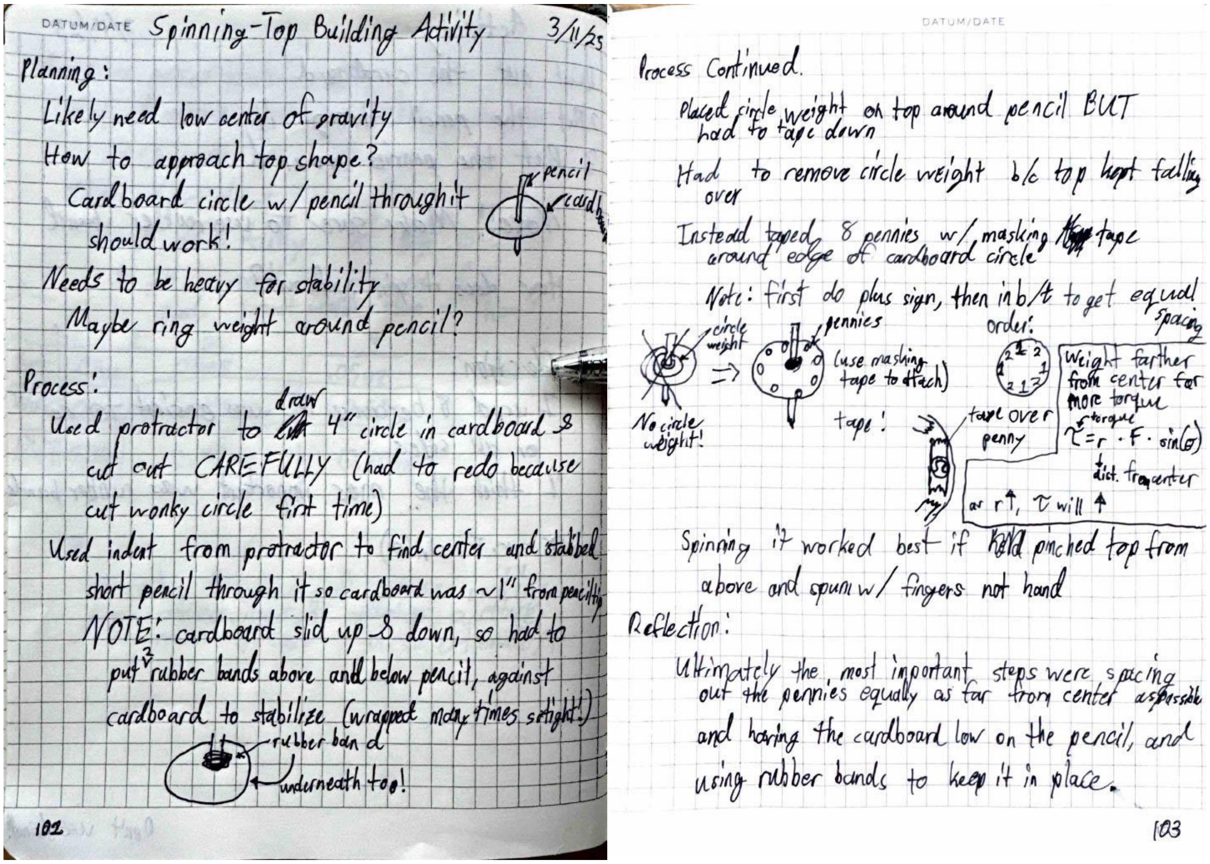
$$\tau = r * F * sin(\theta)$$

Don't use donut!

(b)

Figure 2**: "Flawed" documentation from Stage 1 of the spinning top implementation of the activity. 2a (Top)* *shows the initial handwritten notes provided for students to recreate a spinning top.* ***2b (Bottom) *is the typed transcript for legibility. The documentation meets initial student expectations, however, it relies on subjective, narrative instructions and lacks detail or specificity. See Figure 3 for examples of artifacts made by students from these flawed notes.*

***Figure 3**: **Example student-made artifacts from Stage 1 of the spinning top implementation of the activity.** Due to the logic gaps and subjective language in the initial "flawed" documentation, student recreations diverged significantly from the target concept. These artifacts illustrate the real-world consequences of ambiguous documentation, ranging from incorrect structural assembly to the complete abandonment of the intended mechanical function.*



(a)

Spinning-Top Building Activity 3/11/25

Planning:
Likely need low center of gravity
How to approach top shape?
Cardboard circle w/ pencil through it should work!
Needs to be heavy for stability
Maybe ring weight around pencil?

Process:
Used protractor to draw 4” circle in cardboard & cut out CAREFULLY (had to redo because cut wonky circle first time)
Used indent from protractor to find center and stabbed short pencil through it so cardboard was ~1” from pencil tip
NOTE: cardboard slid up & down, so had to put 3 rubber bands above and below pencil, against cardboard to stabilize (wrapped many times tight!))

Process Continued:
Placed circle weight on top around pencil BUT had to tape down
Had to remove circle weight b/c top kept falling over
Instead taped 8 pennies w/ masking tape around edge of cardboard circle

Note: first do plus sign, then in b/t to get equal spacing

Weight farther from center for more torque

Spinning it worked best if ~~held~~ pinched top from above and spun w/ fingers not hand

Reflection:
Ultimately the most important steps were spacing out the pennies equally as far from center as possible and having the cardboard low on the pencil, and using rubber bands to keep it in place.

(b)

Figure 4**: "High-Quality" documentation from Stage 2 of the spinning top implementation of the activity. 4a (Top)* *shows the handwritten notes provided during the second phase of the activity.* ***4b (Bottom) *is the typed transcript. Unlike the narrative style seen in Figure 2, this approach demonstrates a shift to professional standards by incorporating components such as a pre-execution plan, real-time logging of actions, and active self-correction, providing a verifiable record of the process. Of note, these notes are not perfect and do still contain some mistakes, however, the technical detail and specificity provided allow the reader to identify and navigate these discrepancies, ensuring the artifact remains reproducible despite individual human error. See Figure 5 for examples of artifacts made by students from these high-quality notes.*

***Figure 5**: Successful student-made artifacts from Stage 2 of the spinning top implementation of the activity.* *Unlike the varied results in Figure 3, these artifacts show high consistency and alignment with the target design. This uniformity validates the effectiveness of the student-developed guidelines and demonstrates the successful application of professional documentation standards to reach a functional engineering outcome.*

Appendix B: Materials for a shorter implementation of Recreate given time constraints

(a) (b)

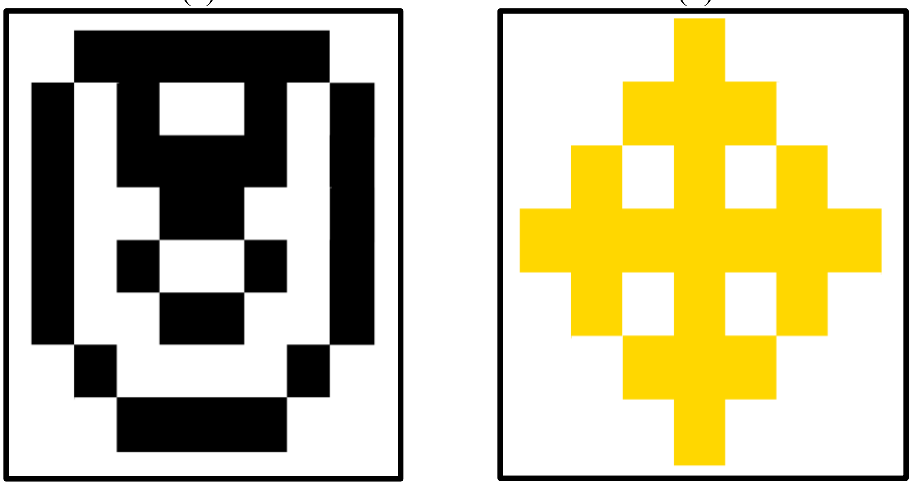


Figure 6: Example Carrier for a short or low cognitive load Recreate. 6a (LHS) *depicts the initial artifact used during Stage 1 of the pixel-art implementation of the activity, designed to elicit productive failure through flawed documentation.* ***6b (RHS)*** *represents the artifact used during Stage 2 to demonstrate the successful application of professional documentation standards. Both artifacts are intended for students to recreate; however, the difficulty or ease of the task is dictated by the quality of the documentation provided in Stage 1 versus Stage 2.*

Started with wide bar all the way across
Added pillars to frame it

Left a couple spaces open in the top half so it didn't feel like one block
Middle section mostly filled in - make sure two sides look even!
Some gaps left in middle rows so there was definition, roughly centered

Lower half narrowed in, added openings to suggest features
Tapered bottom so the figure closed in towards the base
Finished with a shorter row at the bottom so it didn't extend all the way across

Kept left and right consistent where possible
Widths matched visually to maintain proportion
Openings spaced to avoid large solid blocks

Looks like original picture

(a)

Started with a wide bar across the top, kept it about the same width all the way across.
Added pillars down both sides to frame it.

Left a couple of spaces open in the top half so it didn't feel like one big block.
Middle section mostly filled in, making sure the two sides looked even.
Some gaps left in the middle rows so there was definition, roughly centered.

Lower half: narrowed it in, added openings to suggest features.
Tapered the bottom so the figure closed in toward the base.
Finished with a shorter row at the bottom so it didn't extend all the way across.

kept left and right consistent where possible.
widths matched visually to maintain proportion.
openings spaced to avoid large solid blocks.
looks like the original picture

(b)

***Figure** 7: **"Flawed" documentation from Stage 1 of the pixel-art implementation of the activity. 7a (Top)** shows the initial handwritten notes provided to students for the recreation task. 7**b (Bottom)** is the typed transcript for legibility. The documentation meets initial student expectations, however, it relies on subjective, narrative instructions and lacks detail or specificity, ensuring the resulting artifact (see Figure 6a) is not reproducible.*

8/25/25 Fig.B - Puzzle Solver

Goal

Reconstruct Figure A for visual puzzle solution

Plan of Attack

Use default 7x7 grid (Col. A-G, rows 1-7)

Work log

Color hex: #ffd700 (yellow) for all filled in spaces

R1: D
R2: C-E
R3: B, D, F
R4: A-G
R5: B, D, F
R6: C-E
R7: D

Checks

Shape height: 7 rows
Widest: Row4 (7 across, A-G)
Narrowest: Row 1-7 (only 1 cell)
Center column = D, symmetry confirmed left/right

Observations

Star tapers smoothly to points on all 4 sides

Visual match identified!

(a)

8/25/25

Figure B – Star Pixel Grid Notes

Goal:
Document Figure B - enough clarity for future record keeping & evidence

Plan of Attack
- One cell = one pixel.
- Use yellow fill for star cells.
- Work row by row from top to bottom.
- Confirm symmetry across center column (D).
- Record exact filled cells.

Work Log
Row 1: D
Row 2: C–E
Row 3: B, D, F
Row 4: A–G
Row 5: B, D, F
Row 6: C–E
Row 7: D

Mistakes & Adjustments
- At first skipped row 5, realized it repeats row 3. Corrected to include it.
- Thought row 4 was only 5 wide, but verified it spans A–G (7 wide).

Checks
- Center column = D, symmetry confirmed left/right.
- Widest = row 4 (7 cells).
- Narrowest = rows 1 and 7 (1 cell).
- Total height = 7 rows.

Observations
- Star tapers smoothly to points at top and bottom.

Visual match identified!

(b)

Figure 8: "High-Quality" documentation from Stage 2 of the pixel-art implementation of the activity. 8a (Top) *shows the handwritten notes provided during the second phase of the activity.* ***8b (Bottom)*** *is the typed transcript. Unlike the narrative style seen in Figure 7, this approach demonstrates a shift to professional standards by incorporating components such as a pre-execution plan, real-time logging of actions, and active self-correction, providing a verifiable record of the process that ensures the artifact (see Figure 6b) is reproducible.*