Poetry writing to enhance conceptual understanding of mathematical models and approaches for inventory management

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Abstract

To enhance conceptual understanding of mathematical models for inventory management, poetry-writing assignments were developed for a required, upper-level undergraduate course in an industrial and systems engineering program. Specifically, two poetry-writing assignments were incorporated into an inventory and supply chain system design and control course. The first assignment, due one week before the first term exam, asked students to write a poem about a concept, model, or topic related to deterministic inventory modeling. The second assignment, due one week before the second term exam, asked the students to write a poem about a concept, model, or topic related to stochastic inventory modeling. The students were also asked to respond to several open-ended questions on their approach to writing the poems. Data was collected in Spring 2022 semester. Out of 71 students enrolled in the course, 50 gave consent to participate in the study. The student responses to open-ended questions were analyzed to understand students' approach to the poetry-writing assignment. Also, the student-written poems were analyzed for correctness and to identify misunderstandings or gaps in understanding. Findings from the content analysis of student responses and student-written poems are presented.

Keywords. Poetry, inventory control, conceptual understanding, mathematical modeling.

Introduction

In 2007, the Americans for the Arts National Policy Roundtable discussion the development of creativity and innovation skills for success in a global workplace and the role of the arts to this end in response to the need to increase student interest and skills in Science, Technology, Engineering, and Mathematics (STEM) fields. STEAM pedagogy advocates for the integration of the arts with STEM subjects to improve student engagement, creativity, and innovation. Since its introduction, STEAM curricula have been developed for K-12 settings as well as 2-year and 4-year institutions. While STEAM curricula create space for multiple ways of knowing and new paths to equitable learning, STEAM theory, pedagogy, and practice are not clearly defined [1,2]. Furthermore, there appears to be an overall lack of measurements of gain in creativity skills [3]. Despite the ongoing debate, the potential of STEAM curricula to make education more all-inclusive and effective is too important to ignore [1].

To enhance imaginative and creative thinking skills of undergraduate students in industrial and systems engineering, poetry-writing assignments were incorporated into a required upper-level course that focused on the modeling and analysis of inventory and supply chain systems in a large public university's industrial and systems engineering curriculum [4]. An assessment of student perceptions of these assignments revealed that poetry writing not only provided the students with an opportunity to practice their imaginative and creative thinking skills as expected but strengthened their conceptual understanding of the technical material as well [5]. To this end, additional poetry writing assignments focusing on specific course topics were incorporated. The students were asked to create a poem focusing on deterministic inventory modeling before the first term and to create another poem focusing on stochastic inventory modeling before the

second term exam. The first and second term exams cover deterministic and stochastic inventory models, respectively. The students responded to several open-ended questions on their approach to writing the poems.

There is literature that explores various facets on the use of poetry in science and engineering education for the development of various skills. Reviews of existing work in undergraduate engineering exist [4, 5]. An examination of the existing work reveals that there are several important questions that remain in this area. In this paper, our aim is two-fold: (1) How are the students approaching the assignment of creating poems on technical topics? (2) How can the instructor use the student-written poems to identify and address the gaps and/or misunderstandings in students' conceptual understanding of the technical material?

The remainder of the paper is organized as follows: The course and the poetry-writing assignments are described in the following section. After describing data collection methods and approaches, results from data analysis and a discussion of findings are presented. The last section provides concluding remarks and identifies potential avenues for future work.

Data Collection

Course Overview. The overall aim of the course is to develop modeling and analysis abilities of students for the investigation of inventory, logistics, and supply chain problems faced by today's firms. The specific topics include a brief introduction into inventory management systems (focusing on definitions, inventory-related costs, motivations to keep inventory, and distribution value analysis); deterministic inventory modeling (concentrating on economic order quantity and its extensions); stochastic inventory modeling (describing single-period and multiple-period newsvendor models, (q,r) policy with backlogging and lost sales as well as service levels); logistics system design (transportation-related decisions and their impact on inventory decisions); supply chain management and system design (The Bullwhip Effect and simple one vendor-one buyer supply chain system); and demand forecasting (focusing on stationary, linear trend, and seasonal demand processes).

Course Material. The course is designed for lecture-based in-person delivery. There is no required textbook for the course. However, students are provided with detailed lecture notes as well as slide decks. The instructor's lecture notes provide detailed discussions of concepts, technical derivations, and solutions to example problems. The lecture notes are the primary resource for the technical content in the course. The slide decks are designed to navigate the students through the lecture notes during class discussions. To supplement lecture content and facilitate in-class discussion to relate the course topics to real-life applications, reading assignments from current news media, along with articles from relevant business and trade organizations as well as podcast episodes or short films created by businesses or business media, are used.

Course Assessment. To assess student knowledge and skill acquisition, students are given two midterm exams during the semester and a comprehensive final exam at the end of the semester. While the first term exam focuses solely on deterministic inventory modeling, the second term exam addresses stochastic inventory modeling only. The purpose is to ensure that the students

develop a strong foundation in deterministic and stochastic modeling of inventory problems. The students can then use this foundation to address logistics and supply chain system design problems.

The material that relates to deterministic and stochastic modeling of inventory problems spans about the first 8 weeks of a 15-week semester. As this material serves as a basis to enable the exploration of more realistic problems that arise in the context of logistics and supply chain systems, it is not sufficient for students to develop a thorough understanding of the application of the formulas (e.g., for the identification of the economic order quantity or the optimal order quantity or the reorder level for a (q,r) policy) to obtain solutions to given problem instances (i.e., *procedural* knowledge) only. The students also need to understand the modeling assumptions and the implications of such assumptions on model results so that they can understand the applicability and limitations of such fundamental results (i.e., *conceptual* knowledge). That is, the students need a strong understanding of *both* procedural and conceptual knowledge in deterministic and stochastic modeling of inventory problems.

While procedural understanding relates to solving a given problem with given equations, conceptual understanding relates to reasoning and/or interpreting information. For instance, consider the economic order quantity model, a fundamental deterministic inventory model that is often used to address the inventory management component of more complex logistics and supply chain problems. Procedural learning in this modeling context focuses on the development of the ability to identify the relevant problem parameters and evaluate the optimal order quantity, the associated average annual total cost, and perhaps the optimal inventory cycle length by applying the associated formulas for the economic order quantity model. In contrast, conceptual learning in this context focuses on the development of an understanding of the (i) meaning, implications, and limitations of the basic modeling assumptions of the economic order quantity model [e.g., known and constant continuous demand rate, infinite planning horizon, and known and constant cost parameters] in a real-life problem context. While the former can be developed by problem-solving, the latter can be achieved by inviting the student to make meaning of the technical knowledge.

Course Design. The course was designed to facilitate the development of both procedural and conceptual understanding of the material. To facilitate procedural learning, at least one example problem instance was solved in class. Also, additional problem sets with solutions were provided in the detailed lecture notes to provide ample opportunities for students to work on various practice problems. To support conceptual learning, both technical and creative writing assignments were used to invite students to make their own meaning of the course material. For technical writing, the students are asked to provide brief memos presenting their analysis of various aspects of inventory and supply chain systems. For instance, while one assignment required students to collect selling price data for competing brands of a consumer product on both brick-and-mortar and on-line retail channels, analyze the data, and summarize their observations, another assignment required students to listen to a podcast or read a newspaper article that described the supply chain operations of a company and create a high-level supply chain operations map of the company. The purpose was to give students an opportunity to interpret the meaning and implications of the course material in practical applications that they may encounter. For creative writing, the students were asked to write two technical poems and

reflect on their experience of technical writing poetry in an inventory and supply chain systems course. Table 1 provides an overview of the entire creative writing component of the course. This paper focuses on Poems 2 and 3 along with Reflections 1 and 2.

Table 1. Assignments for the creative writing component of the course.

Assignment	Brief description	Contribution to overall course grade
Poem 1	A poem about oneself	1%
Poem 2	A poem about a concept related to deterministic inventory modeling	1%
Reflection 1	Reflecting on one's experience of writing Poem 2	1%
Poem 3	A poem about a concept related to stochastic inventory modeling	1%
Reflection 2	Reflecting on one's experience of writing Poem 3	1%
Reflection 3	Reflecting on one's overall experience of creating technical poetry	1%

For the poem-writing assignments, students were required to use the structure of an "I am" poem (see Appendix A). An "I am" poem relies on personification, a literary device that either allows a non-human object to embody and display affect-, cognition-, and/or behavior-based human attributes. An "I am" poem has a simple structure, and the structure inherently provides detailed instructions on how to create an "I am" poem in a straightforward manner. Hence, even the students with little or no interest and/or experience in creative writing and/or poetry can create an "I am" poem by following these instructions, eliminating the need for additional instruction or training in poetry writing [4, 5]. While the purpose of Poem 1 is to give the students an opportunity to familiarize themselves with the "I am" poem structure, the purpose of Poems 2 and 3 is to invite students to integrate the knowledge and make sense of their learning experience associated with a concept, a model, a topic, or an issue that they are introduced to in the course in the context of deterministic and stochastic inventory modeling, respectively, through a creative experience using this specific poetic structure. Table 2 details the instructions provided for Poems 1 through 3.

Table 2. Student instructions for technical poem-writing assignments.

Assignment	**Instructions**
Poem 1	Write an "I am" poem about yourself using the poem structure provided.
Poem 2	Write an "I am" poem about a model, topic, issue, algorithm, approach or concept related to the course content related to *Basics of Inventory Management and Deterministic Inventory Modeling (i.e., preliminaries on inventory management, ABC Analysis, and economic order quantity model and its extensions)*. From among the choices, be sure to pick a topic that you do not feel comfortable with, are not confident about, or are unclear about. You may use the root verbs given in the original poem structure provided or you may change the root verbs as you fit. Please append the following line to the poem as the last line to state the topic of the poem: I am the (model/topic/issue/algorithm/approach/concept)
Poem 3	Write an "I am" poem about a model, topic, issue, algorithm, approach or concept related to the course content related to *Stochastic Inventory Modeling (i.e., single-period newsvendor model, multiple-period newsvendor model under full backlogging, multiple-period newsvendor model under lost sales, demand during lead time distribution, (q,r) policy with backlogging, (q,r) policy with lost sales, service levels)*. From among the choices, be sure to pick a topic that you do not feel comfortable with, are not confident about, or are unclear about. You may use the root verbs given in the original poem structure provided or you may change the root verbs as you fit. Please append the following line to the poem as the last line to state the topic of the poem: I am the (model/topic/issue/algorithm/approach/concept)

Each student's poem was graded out of 10 points for completeness. For Poem 1, students received full credit if they submitted their poems. For Poems 2 and 3, no points were taken off for technical accuracy. However, students were given individual feedback on their poems, pointing out implied technical inaccuracies and providing suggested improvements. Furthermore, the instructor compiled the most encountered errors that indicate gaps in student understanding into a slide deck and went over them, discussing the issues and how issues can be addressed.

To understand how students approached creating these technical poems, students were invited to reflect on their experience within a week or two after they submitted Poems 2 and 3. The student responses to reflection prompts were collected by setting up 60-minute, online, multiple-attempt quizzes via the course delivery software. Table 3 provides the instructions and prompts used in the assignments that prompted students to reflect on their experience of technical poetry writing. Each student's reflection was also graded out of 10 points. Students received full credit score if they submitted responses to all prompts.

Table 3. Student instructions and question prompts for reflection assignments.

Assignment	Instructions and questions
Reflection 1	*Instructions*. There are three short-essay questions on this quiz. The questions will ask you to reflect on Poem 2 that you have submitted before Term Exam 1. A time limit of 60 minutes is set which should be more than ample time to respond to the questions. *Questions*. 1. [4 points] How and why did you choose the particular topic for your "I am" poem on Deterministic Inventory Modeling? 2. [4 points] What course materials and other resources did you use to create your "I am" poem focusing on a topic related to Deterministic Inventory Modeling? 3. [3 points] Provide an estimate of the amount of time it took you to create your "I am" poem on Deterministic Inventory Modeling from preparation and resource gathering through submission of the assignment.
Reflection 2	*Instructions*. There are three short-essay questions on this quiz. The questions will ask you to reflect on Poem 3 that you have submitted before Term Exam 2. A time limit of 60 minutes is set which should be more than ample time to respond to the questions. *Questions*. 1. [4 points] How and why did you choose the particular topic for your "I am" poem on Stochastic Inventory Modeling? 2. [4 points] What course materials and other resources did you use to create your "I am" poem focusing on a topic related to Stochastic Inventory Modeling? 3. [3 points] Provide an estimate of the amount of time it took you to create your "I am" poem on Stochastic Inventory Modeling from preparation and resource gathering through submission of the assignment.

Data Collection. The data for the current study was collected in Spring 2022 semester, when the course was offered in two sections. Class meetings were on Mondays, Wednesdays, and Fridays. While Section 1 had 44 students enrolled, Section 2 had 27 students. In Spring 2022, the institution was still completing its transition from a hybrid on-line format to fully on-campus format. The instructors were informed that they could teach until the end of January via Zoom or HyFlex, if they preferred to ensure that the students returning to campus could ease into the transition. The instructor continued to teach via HyFlex and create recordings of classroom

discussions throughout the semester. Although the course content was the same, two separate recordings for each section were made most of the time. Both recordings were made available to all students enrolled in the course regardless of their individual section designation.

The creative writing assignments were a mandatory component of the course, and these assignments were graded anonymously throughout the semester. At the end of the semester, a total of 50 students out of 71 gave consent for their poems, and their responses to the reflection prompts to be included in the study. Their work was de-identified and entered as data for the study. Table 4 presents the fraction of students who consented to participate in the study, whereas Table 5 provides the sample sizes for each of the creative writing components of the course (i.e., data collection instruments). Each participant in Section 1 was assigned a random number between 1 and 34 and each participant in Section 2 was assigned a random number between 1 and 16 during the data identification process. In the remainder of the document, *x-yyy-z* denotes the response of participant *yyy* to prompt *z* for poem *x*.

Table 4. Number and percentage of students who consented to participate in the study.

	Section 1	Section 2	Overall class
Number enrolled	44	27	71
Number consented	34	16	50
Percentage participated	77.3	59.3	70.4

Table 5. Sample size for each data collection instrument.

Assignment	Section 1	Section 2	Overall class
Poem 2: Deterministic Inventory Modeling	34	16	50
Reflection 1	33	16	49
Poem 3: Stochastic Inventory Modeling	34	16	50
Reflection 2	34	16	50

Data Analysis and Results

Topic. To identify the specific inventory-related topic chosen, participant responses to Prompt 1 in Reflections 1 and 2 were analyzed qualitatively using open and axial coding by two researchers (XX, YY). The codes that emerged from the analysis of Poem 2 include *preliminaries*, the *ABC analysis*, and the *EOQ model*, whereas the analysis of Poem 3 yielded codes of *preliminaries*, the *newsvendor model*, and the (*q,r*) *policy*. If a participant did not explicitly specify the topic of their poem in their response, then these responses received a code of *undeclared* for topic. If a participant declared a topic, but the topic was not in the set from which the topic had to be chosen for the assignment, these responses were assigned a code of *miscellaneous*. For example, a participant created a poem about supply chain crisis for Poem 2, and their response was coded as miscellaneous. Similarly, another participant created a poem about the 80-20 rule for Poem 3, their response was coded as miscellaneous as well. Each response received a single topic code. Tables 6 and 7 present the frequency of the topics that were selected by the students on deterministic and stochastic inventory modeling, respectively.

Table 6. Frequency of various deterministic inventory modeling topics selected by participants.

	Preliminaries	ABC Analysis	EOQ Model	Miscellaneous	Undeclared	Total
Section 1	2	14	12	1	4	33
Section 2	5	5	5		1	16
Class total	7	19	17	1	5	49

Table 7. Frequency of various stochastic inventory modeling topics selected by participants.

	Preliminaries	Newsvendor	(q,r) policy	Miscellaneous	Undeclared	Total
Section 1	1	23	3	1	6	34
Section 2	2	10	1		3	16
Class total	3	33	4	1	9	50

Resources. To understand the resources used in the creation of poems, participant responses to Prompt 2 in Reflections 1 and 2 were analyzed qualitatively using open and axial coding by two researchers (XX, YY). The codes that emerged from the analysis were *lecture notes*, *slide decks*, *class discussions*, *personal notes*, *online research*, and *other*. *Lecture notes* and *slide decks* correspond to the standard material for the course, which are the detailed lecture notes provided by the instructor and the slide decks used to guide and support in-class discussion, respectively, as mentioned earlier. *Class discussion* corresponds to the material (discussion and/or explanation) delivered by the instructor during class meetings, and participant responses that mentioned watching class recordings or attending lectures or remembering knowledge presented during class meetings, etc. received this code. *Personal note* corresponds to the written material that the participants generated for themselves during class meetings which can be annotations on slide decks (in printed or electronic form) or notes generated by the student in a notebook (physical or in a computer pad), and participant responses that mentioned personal notes or annotations received this code. *Online research* corresponds to the resources (e.g., YouTube videos, materials published by other instructors in other institutions, Wikipedia, etc.) that the participants were able to identify themselves, and participant responses that mentioned any online resource received this code. *Other* corresponds to other inputs to the process of creating poems that the participants mentioned. For example, responses that included “earlier I am poems” [3-125-3], “my understanding” [2-127-3], or “the (poem) template” [2-212-3] received this code. There are also some participants whose answers to the prompts did not reveal specific resources which received a code *not specified*. Table 8 presents the frequency at which participants utilized various resources to create their poems.

Table 8. Resources used by participants for the creation of (a) Poem 2 and (b) Poem 3.

		Resource							
		Lecture notes	Slide decks	Class discussion	Personal note	On-line research	Other	Not specified	Total
Poem 2	Section 1	10	27	11	7	12	3	1	71
	Section 2	6	15	6	6	4			37
	Class total	16	42	17	13	16	3	1	108

(a)

		Resource							
		Lecture notes	Slide decks	Class discussion	Personal note	On-line research	Other	Not specified	Total
Poem 3	Section 1	6	18	5	6	9	1		45
	Section 2	3	10	4	4	5			26
	Class total	9	28	6	9	8	1		71

(b)

Note that if a participant has personal notes to review, this implies that they have attended the class meeting or watched the recording of the class meeting. This implied relationship was not considered in the analysis. Only the responses of the participants who explicitly mentioned their recall of the in-class discussion or their watching or rewatching corresponding recordings were assigned class discussion code.

Estimated Duration. To understand the time requirement of a poem-writing assignment, participant responses to Prompt 2 in Reflections 1 and 2 were analyzed qualitatively using open coding by two researchers (XX, YY). While some participants provided durations in hours, others expressed these estimates in minutes. All participant responses were mapped to minutes first. Resulting participant responses could be categorized into four broad categories: One group of participants specified an exact duration (e.g., "1 hour" [3-202-3] or "30" [3-213-3]) whereas others noted estimated durations with a qualifier suggesting reasonable closeness (e.g., "roughly 45" [2-132-2], "around 45" [3-113-3], "about two hours" [2-130-3], and "approximately 90" [3-204-3]). A third group of participants specified a bound (e.g., "an hour maybe a bit over" [2-110-3] or "a little less than 2 hours" [2-129-3]). A fourth group of participants specified a range (e.g., "30-60 minutes" [2-202-3] or "about 2- 2 1/2 hours" [3-103-3]). To consolidate the data in these four different categories, the parameters of a triangular distribution were generated for each data point, as illustrated in Table 10.

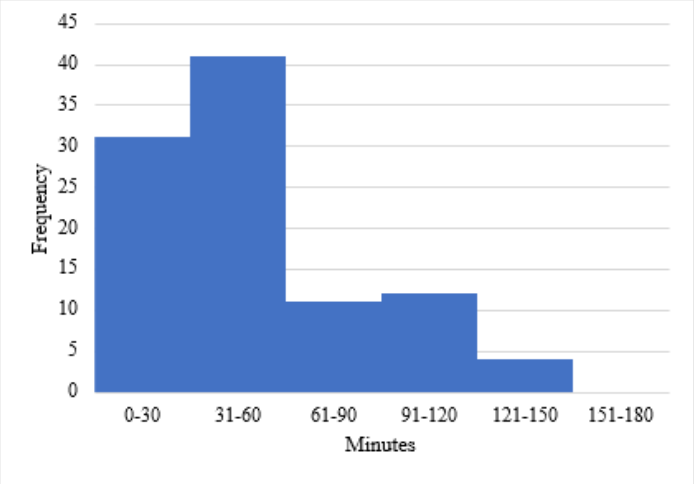
Table 10. The empirical approach is used to estimate the parameters of a triangular distribution based on a participant's response to the estimated duration of a poem-writing assignment.

	Estimated values for the study		
Participant provided data	Minimum	Average	Maximum
x	x	x	x
About/around/approximately y	y	y	y
A little less/more than z	z	z	z
Between x and y	x	$(x+y)/2$	y

Using the approach in Table 1, estimated minimum, average, and maximum values were obtained for each participant. Then, three different sets of frequency distributions (where the

bucket size is 30 minutes) were plotted using minimum, average, and maximum values. A critical examination of the frequency distributions generated using minimum, average, and maximum values did not exhibit substantial variability in distributions. Hence, the frequency distributions that are based on these estimated average values are reported in this paper. Figure 1 shows the frequency distribution of the estimated average time to complete the poem-writing assignments (n=100). Note that data for both poem-writing assignments and from both sections are reported here. The individual frequency distribution plots for the estimated average time to complete each poem-writing assignment and for each section are provided in Appendix B.

Figure 1. Frequency distribution of mean estimated time to complete a poem-writing assignment (n=100)



Furthermore, the degree of elaboration as to how the total estimated time was spent exhibited variability as well. Some participants simply stated a number with no elaboration. (e.g., "30 minutes" [3-104-3]), whereas some participants provided articulated the steps of their processes to create their poems. For example, "To prepare for this assignment I used some time to read about all the possible topics again, I chose one and did some extra research online, and then proceeded to write the main ideas and find the appropriate rhymes. I spend around 20 minutes choosing the topic, 25 doing some extra research, 15 writing the main ideas and an extra 20-30 minutes looking for the best way to put them together creatively. Overall, I spent about 80-90 minutes creating my poem," [3-112-3] described not only the steps but provided estimates for each step as well.

Discussion: Preliminary Insights

Topic. Note that there were nine responses in the data set that received the undeclared category. The research team has these poems, and, hence, could identify the topics chosen by these respondents and assign codes. This was not done for the following reason: There are several poems in the data set for which what the last line claimed that the poem is about versus what the poem was itself about was not always consistent. For instance, a poem can be about the economic order quantity (EOQ), on the EOQ model, or the EOQ Model assumptions. However, a participant who is a novice student in the topic may not have clear distinctions among these

topics or may not have thought about the poem's main topic critically in a sufficient manner to be able to declare it accurately. In order not to introduce any expert bias in the data, for the purposes of the analysis reported here, if the respondent did not clearly articulate the topic of their poem, then their responses were coded as undeclared.

For Poem 2, the top two competing topics picked by the respondents are the ABC Analysis and the EOQ model, which are not surprising as those are the major topic categories in that domain. However, the way students approach these topics exhibit variability. The topic could be sharply focused. For instance, there are two poems, one of which focuses on Class A items and the other one on Class C items. There are poems that focus on the mechanics of the approach. That is, almost a step-by-step description of the distribution value analysis. There are also poems that focus on the implications of the ABC analysis in practical settings. This demonstrates how there are numerous ways how a student can relate to the course material and make meaning for themselves.

For Poem 3, the top topic picked by the respondents is the Newsvendor Model. This is not particularly surprising as it is the first stochastic demand model the students encounter and the discussion of several variants (single-period cost minimization, single-period profit maximization, multiple periods with full backlogging, and multiple-periods with lost sales) provide a rich context.

The Preliminaries category includes poems on a diverse set of topics, including a stock keeping unit, the calculation of the inventory carrying rate, the deterministic modeling of demand, the unit inventory holding cost, an inventory cycle or the constant lead time for Poem 2 as well as the demand during lead time distribution for Poem 3. As the instructions for the assignment invited the students to pick a topic that they were uncomfortable with, these participants revisited the basics to deepen their understanding.

Resources. A comparison of data obtained from Poem 2 and Poem 3 show that the participants reported more resources (n=108) in Reflection 1 and fewer resources (n=71) in Reflection 2. There may be multiple reasons for this, such as a recognition of the fact that they will receive full score for the assignment regardless of the degree of elaboration in their response or being distracted with other assignments and projects when Reflection 2 was due. For Poem 2, the top three resources were slide decks and class discussion, followed by on-line research and lecture notes, tied for third place, whereas for Poem 3, the top three resources were slide decks, lecture notes and personal notes tied for the second place, and on-line research. This indicates that slide decks are the course resources that the students used the most.

One code category that is worthy of additional investigation is the on-line research, which is particularly useful for the student for meaning making. Students were not required to conduct additional research for this assignment. However, the specific resources indicated by these respondents can be categorized into two are summarized in Table 11. As can be seen from the table, these responses can be broadly categorized into two groups. While some respondents needed additional technical information, some others wanted additional information related to literary arts. For instance, various channels on YouTube, investopedia.com, netsuite.com, Supply Chain Resource Cooperative website as well as teaching material posted by other instructors in

other institutions, are mentioned for obtaining additional technical information. Furthermore, some respondents referenced on-line dictionaries, thesauri, or translators to expand their vocabulary or to find rhymes.

Finally, in the miscellaneous category, some respondents mentioned some unique resources. While one respondent stated that their imagination (and even mentioned how they were inspired by some imagery from a Spiderman movie) was a primary resource, another one mentioned their own understanding as a resource. These are interesting observations as they serve as indicators of the meta-cognitive skills demonstrated by these respondents.

Estimated duration. To understand how a poem-writing assignment would compare to other types of assignments in terms of the time a typical student would need to complete, the participants were asked to provide estimates of the total time they spent to complete the poem-writing assignments. For 71 percent (71 out of 100) of the poems in the data set, the average estimated time to complete the poems was reported to be less than one hour, whereas the remaining 29 percent (29 out of 100) were estimated to be completed between 61 and 150 minutes. The frequency distributions obtained for Poems 2 and 3 in Sections 1 and 2 are quite similar. Since stochastic inventory models tend to be more difficult for the students, the average estimated time for Poem 3 was expected to be greater than that for Poem 2. As one participant stated, “It took me about half an hour to decide what i wanted to write about and then an hour and a half to actually write my "I am" poem. However, it took me longer to dive deeper into the topic because (for) this assignment (I) realized I needed to study up more on the model,” [3-131-3], particularly the time allocated to study and review the model was expected to be longer. However, a different effect (i.e., “learning by doing”) might be in play, as several participants noted that the fact that this was the second technical poem that they had to write, they spent less time on it, i.e., “Since I already wrote 2 types of these poems I was able to write this one a bit faster, for this reason I completed the poem in about 25 minutes,” [3-215-3] and “Unlike the previous poem that took me a couple of hours to do, I was able to do this poem in a much shorter amount of time. I would estimate it took me 30 minutes to create my poem. This is probably because of my newfound familiarity with writing these poems. I also tried to make this poem similar to my previous one about Deterministic Inventory Modeling so the comparisons between the two topics would be clearer,” [3-134-3].

Discussion: What Can an Instructor Learn from a Student-Written Poem?

The student-written poems have the potential to provide profound insight into some misunderstandings and/or gaps in student learning. For instance, a critical characteristic of the newsvendor model relates to the two possible outcomes of having too much inventory (i.e., overage) or having too little inventory (i.e., underage). It is possible to conceptualize the newsvendor model in a broader context by considering the perspectives of (i) a setting, (ii) a company that operates in a newsvendor setting, as well as (iii) a customer of this company.

- From the perspective of the newsvendor model setting, overage, and underage are two possible outcomes. Unless the demand observation is exactly equal to the order quantity (the probability of which is zero when the demand is continuously distributed), there will either

be an overage or an underage. Furthermore, neither overage is a worse outcome than underage, nor underage is a worse outcome than overage.

- From the perspective of the company, depending on the corresponding costs, the demand distribution's structural characteristics as well as the implications of either outcome in a broader context (e.g., considering company reputation and customer profile), one outcome may be worse than the other. For instance, a company that is competing on product availability may have less tolerance for underage, whereas a company that is competing on product exclusivity may have more tolerance against it.
- From the perspective of the customer, underage may be a worse outcome than overage. Because underage implies the customer's demand may not be satisfied, which is highly like to be an inconvenience to the customer.

Of these three perspectives, i.e., the model setting, the company, and the customer, the one that an average student in the class is most likely to have is that of the customer. Hence, the student may think that being underage may be worse than overage. An important learning outcome for the student, however, is to recognize that (i) underage and overage are two possible outcomes; (ii) one is not necessarily worse than the other (from a mathematical perspective); and (iii) the relative magnitude of unit costs associated with these outcomes as well as the characteristics of the underlying demand distribution will drive the identification of the optimal order quantity as well as the resulting expected values of the underage and overage quantities.

Next, consider two student-written poems (see Appendix C) on the newsvendor model. The lines 10 and 11 of one of these poems [132] read:

> *I worry I didn't produce enough to satisfy the demand or I made too many*
> *I cry when there is underage or overage*

In this poem, both lines appear to express a negative attitude (i.e., worry and cry) to both the production of too much and too little inventory as well as the outcomes of both underage and overage. In contrast, the lines 10 and 11 of the other poem [122] read:

> *I worry that I will incur a unit cost of overage or underage*
> *I cry when I cannot meet demand*

While a negative attitude (i.e., worry) is expressed towards incurring the unit cost associated with overage and underage, a negative attitude (i.e., cry) is expressed only towards the outcome of having too little inventory. There are no other lines in the rest of the poem that expresses a similar negative attitude to the outcome of having too much inventory. This might be a simple oversight. It might be an artistic choice – it is art, after all. However, this observation may serve as an indicator to the instructor to find ways to ensure that this fundamental characteristic of the newsvendor model is taught and learned comprehensively. Feedback to this end may be given to the student individually or the entire class, both of which were done in this class.

Finally, such an example does not exist in the data set for this study, but it is possible to imagine an instance with two separate lines, one of which expresses a negative attitude towards the outcome of having too little inventory, whereas the other has too little inventory. For instance, "I

worry that I would not meet the entire demand" and "I cry that I would have inventory left over" together could work. There are many possibilities, and the student could pick the one that makes most sense to them as they make meaning of the course material for themselves as a part of their learning process.

Concluding Remarks

To enhance conceptual understanding of mathematical models for inventory management, poetry-writing assignments were developed for a required, upper-level undergraduate course in an industrial and systems engineering curriculum. Data was collected from two sections in Spring 2022 semester. In this paper, some preliminary results on the topics picked by the participants, the resources used by the participant to create their poems, and the estimated time to complete the poem-writing assignment were analyzed. Data analysis on two fronts continue and will be reported during the presentation on student perceptions of the effectiveness of the poem-writing assignments on their learning.

A limitation of the study is the lack of a direct assessment of student learning. That is, although the students may say that the poem-writing assignment helped them learn better, it is not clear if this would also be reflected in their scores on the other assessments used in the class. In a related on-going project, standardized test questions have been developed, and data is being collected to investigate whether improved student learning can be measured via other assessments.

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Appendix A. "I am" Poem Structure

Table A.1. The "I am" poem structure.

I am *(two special characteristics)*
I wonder *(something you are actually curious about)*
I hear (an imaginary sound)
I see (an imaginary sight)
I want (an actual desire)
I am (the first line of the poem restated)
I pretend (something you pretend to do)
I feel (a feeling about something imaginary)
I touch (an imaginary touch)
I worry (something that really bothers you)
I cry (something that makes you very sad)
I am (the first line of the poem repeated)
I understand (something you know is true)
I say (something you believe in)
I dream (something you actually dream about)
I try (something you make an effort to do)
I hope (something you actually hope for)
I am (the first line of the poem repeated)

Appendix B. Detailed Estimated Duration Data

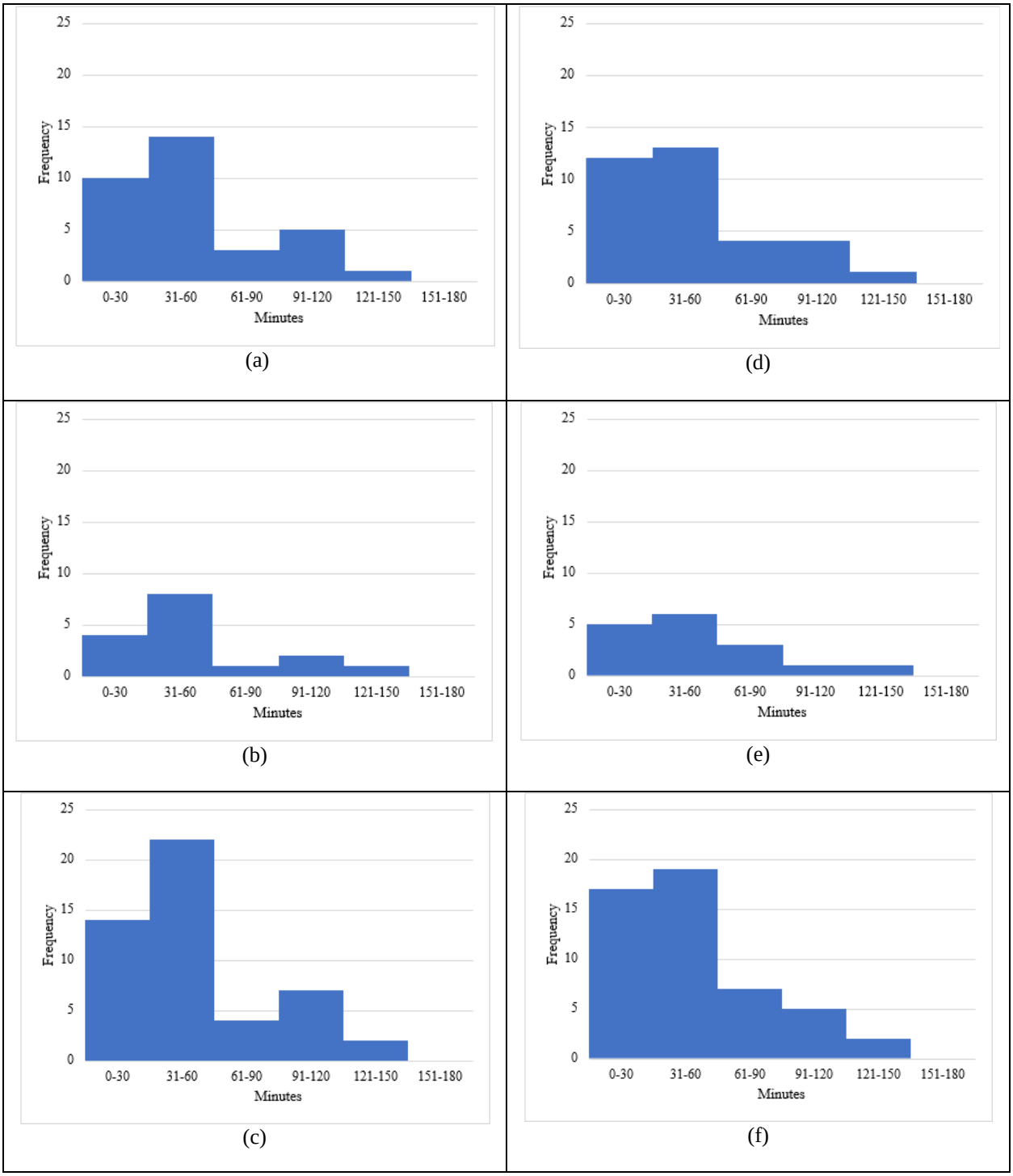

Figure B.1 Frequency distribution of mean estimated time to complete a poem-writing assignment for (a) Poem 2 in Section 1 (n=34), (b) Poem 2 in Section 2 (n=16), and (c) Poem 2 in the class (n=16)as well as for (d) Poem 3 in Section 1 (n=34), (e) Poem 3 in Section 2 (n=16), and (f) Poem 3 in the class (n=16).

Appendix C. Sample Student-Written Poems

Table C.1. The "I am" poem written by a participant (132) on the newsvendor model.

Line count	Line
1	I am minimization of expected total cost or maximization of expected net profit
2	I wonder how much to purchase or produce
3	I hear the inventory being reviewed on a periodic basis
4	I see a single planning period
5	I want to know the critical ratio
6	I am minimization of expected total cost or maximization of expected net profit
7	I pretend the order delivery lead time is zero
8	I feel a loss of goodwill
9	I touch the salvage revenue
10	I worry I didn't produce enough to satisfy the demand or I made too many
11	I cry when there is underage or overage
12	I am minimization of expected total cost or maximization of expected net profit
13	I understand I will incur extra costs
14	I say it can be salvaged
15	I dream I produce to meet the exact demand
16	I try to know the probability distribution for the demand
17	I hope I can find the number of units to order at the start of the period
18	I am minimization of expected total cost or maximization of expected net profit
19	I am the newsvendor single-period model

Table C.2. The "I am" poem written by a participant (122) on the newsvendor model.

Line count	Line
1	I am a stochastic model of demand and have a finite planning horizon.
2	I wonder how much to order each period.
3	I hear the clinking of coins saved through the optimal order quantity.
4	I see the irregularity of the random demand.
5	I want to minimize the expected total cost at the end of the planning period.
6	I am a stochastic model of demand and have a finite planning horizon.
7	I pretend that order delivery lead time is zero.
8	I feel there is no fixed cost associated with placing an order.
9	I touch the emptiness of shortages.
10	I worry that I will incur a unit cost of overage or underage.
11	I cry when I cannot meet demand.
12	I am a stochastic model of demand and have a finite planning horizon.
13	I understand that cost minimization and profit maximization both yield the critical ratio.
14	I say this result is elegant.
15	I dream that I know the underlying probability distribution of the demand.
16	I try to help companies determine their optimal order quantity.
17	I hope people will appreciate my beauty and simplicity.
18	I am a stochastic model of demand and have a finite planning horizon.
19	I am the single period newsvendor model