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Made to order: Python-based approach for creating bespoke problem sets in chemical engineering courses

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Abstract

Engineering education is largely grounded in constructivist principles, where learning outcomes are often enhanced by individualized assessments. Research supports the idea that tailored interventions, designed to meet the specific needs of learners, can foster a more personalized learning experience. A key aspect of this is targeted feedback, which plays a vital role in student development. This study presents a strategy that enables instructors in chemical engineering courses to create bespoke problem sets and solutions tailored for their students. Ethical AI use and intellectual property contributions are discussed extensively in the text. The issues considered were (1) bias in AI-generated problem statements; (2) academic integrity and plagiarism; (3) data privacy and student information; (4) openness and explanation; (5) intellectual property and copyright; and most importantly, (6) the general framework for ethical use of AI in engineering education.

This approach leverages Python programming, using a modular problem generation and function-based strategy to adapt textbook problem sets and similar resources. AI is employed to vary problem statements. Policies and guidelines on copyright and intellectual property should be followed during the AI phase. It is important to modify the additional information that gives context to problems. Instructors can assign unique values for each student. Instructors also need to set appropriate value ranges and ensure that the program accurately generates custom problems and solutions.

Using Python, ten computational lab activities were generated for approximately 130 students in chemical engineering courses, including chemical engineering calculations, momentum transfer, and separation processes. Flowcharts of the functions used, along with sample activities, are provided. The assessments of these lab activities are discussed, along with the challenges and opportunities for expanding this method to other chemical engineering courses.

This Python-based method for generating personalized problem sets has proven promising in promoting individualized learning experiences for chemical engineering students. The approach shows considerable potential for application in a broader range of chemical engineering courses. Further studies are recommended to see how bespoke problem sets can improve student outcomes in other disciplines as well.

Keywords: personalized learning; bespoke problem sets; python programming; chemical engineering education; computational lab activities; targeted feedback; modular problem generation; individualized assessments; engineering education technology; AI in Education

Introduction

Active learning is an important aspect of constructivist education. As engineering educators shift from traditional modes of instruction to more student-centered ones, instructors have been tasked with the task of motivating students' engagement with complex real-world problems in a collaborative environment. In this paradigm, students are encouraged to embrace agency in their learning and take control of their educational journey.

One way to concretize learning is by using individualized problem sets; these are defined as assessment and instructional materials that are varied and adapted to each student. This can be one way to improve the relevance and applicability of course material [1], [2], [3]. The uniqueness of each problem set from the rest requires students to exercise independence and self-directed learning.

The use of custom problem sets is new to engineering education, but a literature search shows that problem sets can help build the foundations of constructivist education. In contrast to passively learning from lectures or activities led by an instructor, cognitivism says that students learn best when they are actively "constructing" or working on the tasks they are given. The use of problem sets can be traced back to the problem-based learning (PBL) model, a direct application of the constructivist philosophy. In one study, PBL is said to focus on real-world problems to stimulate higher-order thinking skills among students. Ultimately, the goal is to promote teamwork and discussion as essential components of the learning process [4]. This is the prime objective for the use of bespoke problem sets. According to another study, social constructivism, which is an extension of the constructivist approach that focuses on social situations, can improve the learning process by including group learning strategies that encourage active participation and building knowledge [5]. While constructivist principles have been embraced in higher education, particularly in assessment, a full and holistic integration is yet to be seen [6].

Further research has explored the effectiveness in enhancing learning outcomes via PBL which demonstrates that it not only improves students' problem-solving skills but also gives them the opportunity to gain a nuanced understanding of problems through collaborative efforts [7]. A meta-analysis of the studies on this issue indicates that constructivist learning models like PBL can improve students' cognitive abilities and more meaningful knowledge generation [4].

Literature has also emphasized the crucial role of instructors in constructivist learning. A study underscores the need for the teacher's role to be transformed from the "sage on the stage" to that of a "guide on the side.". What is essential is to provide students with a learning environment conducive to active learning and critical thinking [8]. Since the constructivist role of the teacher has increased in prevalence in teacher training programs, improvements in student engagement and learning have been observed [9].

Researchers have explored the integration of technology to create constructivist learning environments. Students' comprehension and involvement are improved by interactive multimedia courses, demonstrating how constructivist ideas can be modified for use in contemporary educational settings [10].

According to published research, individual problem sets help students develop and engage with the course material in a way that is consistent with their past experiences and knowledge [11]. In another paper which seeks to explain this, constructivist learning is supported when problem sets reflect realistic contexts. This might be because constructivist learning is rooted in the individual's ability to create meaning from experience [12]. A student-centered approach is crucial in that it supports learners' exploration of the problems relevant to their interests and academic goals [13]. Furthermore, individual problem sets should not only address individual learning needs but also encourage collaboration and interaction among peers, in order to maximize the learning experience [14]. Oftentimes, students may be able to explore multiple solutions to a single problem using individualized problem sets. This encourages critical thinking and allows learners to connect their learning process with real-world contexts. This makes the educational experience more visceral for the student. Emphasis on problem-solving strategies strengthens the principle of individual recognition of value of students' unique perspectives and experiences [17].

Python-generated problem sets could be one way for engineering teachers to integrate technology with problem set construction via the PBL model, since they offer unique opportunities for individualized learning and assessment. The method reported in this paper is unique to all other studies in that it presents a concrete way to personalize and modify problem values for each student and generate the problem sets and answer keys, all using Python programming, for chemical engineering courses. This approach has not been previously reported.

In 2016, Branch and Butterfield presented a project on the development of an online system that generates generating and grading textbook-style homework problem, as well as resource for preparing, evaluating and certifying students for laboratory equipment [15]. While this project shares the spirit and some of the objectives of this work, the difference in programming languages used in this paper (Python) with that of their work (PHP, HTML and Javascript) could be noted. The ability to download individual problem sets that could be printed and given to students was not explored in their study. Over-all their work is highly intricate, as it involved the creation of an entire website, while this project focuses on the mores simple task of the production of problem sets on a batch-individual basis. Also, this work focuses on usage of problem sets for in-person computational labs.

In another work by Kowalski and Snow in 2018, they used the Canvas environment to create four versions of homework problems. They recommended not to use the onboard Canvas multiple version generator as it was the source of most errors in the system [16]. Their preliminary results indicate gains in the median and mean exam scores for participating students. This work proposes a solution to that problem by generating a solution together with the problem output, so that the instructor can verify the accuracy of the problem set prior to assigning it to students.

Even though there are many benefits, making individualized problem sets is still hard for several reasons. These include, but are not limited to, (1) issues with creating content; (2) issues with assessing and giving feedback; (3) limited time and resources;

(4) technological issues; (5) file storage and availability; (6) issues with scalability; (7) issues with implementation and teaching; and finally (8) concerns about AI and intellectual property.

Briefly, (1) refers to the additional steps that may need to be done to ensure curricular alignment with the intended learning outcomes of the course for which the problem set is made. The instructor must accurately balance the depth and breadth of the problems added to the problem set. Furthermore, the problems covered must also accurately portray engineering scenarios in the real world. (2) Because students have different levels of skill, motivation, and learning style, one of the most important things to think about when making a problem set is how fair it is. All students should be able to finish the set fairly, with difficulty and workload being carefully thought out. Assessment and feedback issues are also apparent (3), with personalized problem sets highlighting the need for an automated or mostly automated process. Instructors should be able to provide timely and meaningful feedback as a response to the unique responses and queries of students on problem sets. As for resource and time constraints (3), time management becomes apparent. Since the creation of personalized problems is time-intensive and requires significant effort, it becomes necessary to optimize and automate this process. Furthermore, to increase access, the program should be available as open-source code and made with open-source materials. Technological challenges (4) also present challenges, particularly knowledge of coding and available templates. In addition, the process must also produce content that can be saved electronically and retrieved for future use (5). Scalability (6) concerns the production of individualized problem sets on a large scale while maintaining quality and uniqueness. The program must also be reusable and adaptable to other purposes. The last two challenges, pedagogical (7) and ethical (8), can be analysed jointly. Individual problem sets can challenge students, but designing for cognitive load means that these same problems should not overwhelm students. Part of addressing (8) is overcoming inherent biases.

The project uses programming to address these issues: (1) creating problem sets is automated, which makes it easier for the teacher; (2) giving students feedback is possible individually because answers are generated as part of the problem set creation process; (3) using a program cuts down on the time needed to make custom problem sets compared to the old way of doing things by hand; and (4) the program uses an open source language that can be learned over time (Python). Regarding point (5), the program creates files in locations that the instructor or user can modify or specify. Using a modular Python approach, scalability (6) is addressed by varying the operation of the program by simply changing the number of sets that can be generated by the program. This paper also discusses the pedagogical (7) and ethical considerations (8) in the introduction of this paper.

Addressing AI and Intellectual Property ethical concerns

The project explored six AI and intellectual property-related topics: (1) bias in problem statements made by AI; (2) academic honesty and plagiarism; (3) data privacy and student information; (4) openness and explanation; (5) intellectual property and copyright; and finally, (6) the right way to use AI in engineering education. All of these topics were found to be relevant to this project.

This section explains how to address (1). Findings showed that to minimize the influence of bias, when the AI was asked to make more changes after the first successfully modified problem set, it could make a few more alternate problems sets with different situations. However, after a certain point (approximately after two additional prompts or five total problem statements), the examples became more repetitive and/or impractical; thus, for the time being, around 4-5 alternate scenarios or contexts that made sense could be generated for each problem statement.

Regarding data privacy (3), the program does not require any personally identifiable information to run, although the instructor can place the name of the student on the problem set is desired. This was not done in the project. It is recommended to generate problem sets only with a randomized set number. Instructors can map the randomized set numbers to individual students when handing them out and helping them check their answers.

As for (2) and (5), which deal with intellectual property and attribution, which is considered together in the following section, the major effort should be on proper attribution. Because most AI-generated problem statements and modifications are generally unattributed, it is the responsibility of the educator to follow standard citation practice. This includes both in-text citation and bibliographic citation. The project has found that a bibliography may be sufficient, but in-text citations may be used if they do not interfere with the problem set questions. The best practice is to utilize both methods. Since there is no singular guideline that engineering educators use for citing problem sets used in the problem sets, they assign, the following practices are proposed. In this manner, proper attribution to AI (if it is used), use of copyrighted material, and intellectual property ownership terms are made as clear as possible.

Table 1. Sources/generation methods when assigning problem sets and proposed citation practice

Source/generation method	Proposed citation practice
Problem copied verbatim from textbook	In-text citation using IEEE and bibliographic citation
Problem statement, style and values modified	Bibliographic citation and language containing in the in-text citation of "Modified using AI from [X]"
Original problem statement generated by engineering educator	No citation necessary

Furthermore, the instructor should also avoid over-reliance on AI for problem set generation. Students can get "bored" if content is repetitive and untailored to their learning and course needs. If new AI problems align with the course learning objectives, they have the potential to be effective learning tools. However, generally, the best problem sets tend to those authored by instructors themselves. They have a "humanness" the AI models can't replicate (for now).

For (4), the instructor should carefully review the output of any modification of the problem statement. The proposed citation recommendation also serves an added purpose of informing students of the use of AI-generated content. These practices enhance transparency and explainability of the problem set exercise.

The main idea, which is the moral use of AI in engineering education (6), aims to make sure that all students have equal access to AI-generated problem sets by letting them use AI-assisted learning materials (like this project), regardless of their level of digital literacy. In this project, efforts were made to provide the problem sets in both printed and electronic forms.

Objective

The objectives of the bespoke problem set generation system were (1) to create a unique set of problem set questions for each student using resources using open-source programs and code (for this project, Jupyter Notebook was used, an open-source software that can be used to edit and compile Python code – which itself is an open-source programming language) and (2) to generate answer keys for each problem set, which the instructor can use to guide and assess students in answering the problem set.

Methods

There were four main parts to the project: (1) planning and pre-generating problem sets (which included a short talk about AI and intellectual property issues); (2) program development and Python-based problem set generation; (3) giving students generated problem sets in class; and (4) evaluating the activity afterward through a survey.

Planning and pre-generation of problem sets

This phase involved aligning questions in the problem sets with intended learning outcomes (ILOs) of the courses. The table below presents those ILOs.

Table 2. Intended Learning Outcomes of Dry Lab Activities

Chemical Engineering Calculations	DL1: Units and Dimensional Analysis Calculate unit conversions between SI and AES units
	DL2: Matrices in Material Balances Solve matrix problems that will be used to solve material balance problems
	DL3: Material Balances in Multiple Units Analyze material balances by applying conservation principles. Calculate the composition and mass or volume of process streams
	DL4: Material Balances in Unit Operations Calculate material balances for unit operations involving evaporation, crystallization, leaching, and drying. Analyze process streams to determine compositions and flow rates based on chemical engineering principles. Evaluate the efficiency of unit operations using given process data and assumptions.

Table 2 continued. Intended Learning Outcomes of Dry Lab Activities

Chemical Engineering Calculations	DL1: Units and Dimensional Analysis Calculate unit conversions between SI and AES units
	DL2: Matrices in Material Balances Solve matrix problems that will be used to solve material balance problems
	DL3: Material Balances in Multiple Units Analyze material balances by applying conservation principles. Calculate the composition and mass or volume of process streams
	DL4: Material Balances in Unit Operations Calculate material balances for unit operations involving evaporation, crystallization, leaching, and drying. Analyze process streams to determine compositions and flow rates based on chemical engineering principles. Evaluate the efficiency of unit operations using given process data and assumptions.
Momentum Transfer	DL1 - Units and Dimensional Analysis Utilize reference materials (Perry's Handbook for Chemical Engineers) to retrieve and interpret data for engineering applications. Complete detailed tables of physical properties, ensuring accuracy and consistency across data points. Analyze the relationships between temperature and density for organic and inorganic liquids.
	DL2 - Pressure and Fluid Statics Apply principles of pressure and fluid statics to solve real-world engineering problems. Analyze scenarios involving manometers, hydrostatic forces, buoyancy, and fluid separation. Perform calculations involving specific gravity, density, hydrostatic force, and residence time in fluid systems. Design scaled-up equipment based on operational requirements and process parameters.
	DL3 - Newton's Law of Viscosity Apply fundamental principles of fluid mechanics to determine fluid properties such as viscosity, shear stress, and surface tension in various scenarios. Analyze relationships between physical parameters (e.g., force, velocity, diameter, and density) to solve real-world problems involving fluid systems. Calculate fluid flow and interfacial properties using both SI and Imperial units, ensuring precision and unit consistency. Evaluate capillary effects in natural and engineered systems, considering the impact of surface tension and contact angles.

	Integrate theoretical concepts of momentum transfer with practical applications in viscometry, capillary action, and interfacial phenomena.
	DL4 - Continuity Equation and Frictional Losses in Pipes Apply principles of fluid mechanics to solve problems involving viscosity, frictional losses, mass conservation, and mechanical energy. Analyze the flow of fluids in different systems (e.g., pipes, nozzles, and turbines) using theoretical models and experimental data. Calculate viscosity, friction loss, mass flow rates, volume flow rates, and efficiency in various momentum transfer applications. Evaluate the performance of fluid systems and assess improvements or variations in system design (e.g., smooth vs. commercial pipes). Integrate conservation laws and energy principles to assess the efficiency of mechanical systems such as turbines and generators.
	DL5 - Bernoulli Equation and Mechanical Energy Balances
Separation Processes	DL1 - Review of Mass Balances in Separation Processes Apply mass balance principles to analyze and solve problems involving separation processes such as extraction, distillation, and phase separation. Calculate key parameters including recovery percentages, phase compositions, and flow rates in various separation scenarios. Analyze multicomponent systems to determine the distribution of components across different phases or process streams. Evaluate the efficiency of separation processes by determining percent recovery and product purity.
	DL2 - Single Stage Leaching and Liquid-liquid Extraction Apply fundamental principles of leaching and liquid-liquid extraction to analyze single-stage separation processes. Design process flow diagrams (PFDs) to visually represent the steps and stream flows in leaching and extraction operations. Calculate key process parameters, including the amounts and compositions of streams (e.g., overflow, underflow, extract, and raffinate phases). Construct diagrams, plots and ternary diagrams to interpret and validate process equilibrium and mass transfer data. Evaluate the efficiency of separation methods by determining equilibrium compositions and the distribution of components between phases. Integrate theoretical knowledge with practical data (e.g., Perry’s Handbook) to solve complex separation problems involving multiple components.

Regarding the baseline level of competency of students on these outcomes, this was not explored in the study, but in future iterations, it will be measured via pre-test.

Some questions were adapted from textbook exercises, while other problems were written for the project. For those that were adapted from textbooks, some sets were generated using the original problem statements, while in others, the problem set was modified using AI tools, which included ChatGPT and Google Gemini. Other AI chatbot tools were not used during the project.

AI could be utilized to change the language, style, and context of problem sets by changing the content and style of the problems. This is particularly useful in the process of keeping assessments "fresh" or adaptable. The instructor of the course does need to evaluate if the modified problem statement makes sense and is appropriate for the activity.

Table 3. An example of problem statement modification using AI

Original problem statement (containing the placeholders in the problem statement)	AI-modified problem (via change in context)
Roasted copper ore containing the copper as $CuSO_4$ is to be extracted in a single-stage leaching process. Each hour a charge consisting of {{var1-1}} tons of inert solids, {{var1-2}}tons of copper sulfate, and {{var1-3}}ton of water is to be treated. About 1 ton of inert solids retains {{var1-4}} tons of adhering solution. Suppose {{var1-5}} tons of water is used for this process. *Problem obtained from McCabe, Smith and Harriet Unit Operations 7th Ed textbook - 23.1*	Crushed sugarcane containing sucrose as a soluble component is to be processed in a single-stage extraction system. Each hour, a feed mixture consisting of {{var1-1}} tons of fibrous solids, {{var1-2}} tons of sucrose, and {{var1-3}} ton of residual moisture is to be treated. About 1 ton of fibrous solids retains {{var1-4}} tons of adhering solution after extraction. Suppose {{var1-5}} tons of fresh water is used for this process. *Prompt used: "Modify the following problem statement by changing the context of the following problem"*

In this example, the problem originally featured the leaching of roasted copper ore, while the modified problem replaces the copper sulfate as the soluble solid with sugar. Although dealing with different materials, the same analysis is asked of the student—to calculate the number of stages required.

Program Development and Python-based problem set generation

The process of making a custom problem set is based on modules, which are based on object-oriented programming. However, the main focus is still on functions written in Python that are used to (1) generate random sets of given values and (2) find the desired quantities for each problem using functions written specifically for that problem set.

A function-based approach was used as the core of the program. The Python code was compiled in Jupyter Notebook. After randomized values are selected, these values are fed to the function, which calculates the desired required values. All of this information is stored as a CSV file for grading and advising students.

AI can help educators create individualized problem sets by (1) customizing problem statements to the local setting and (2) brainstorming alternative situations where the same Python function can be used.

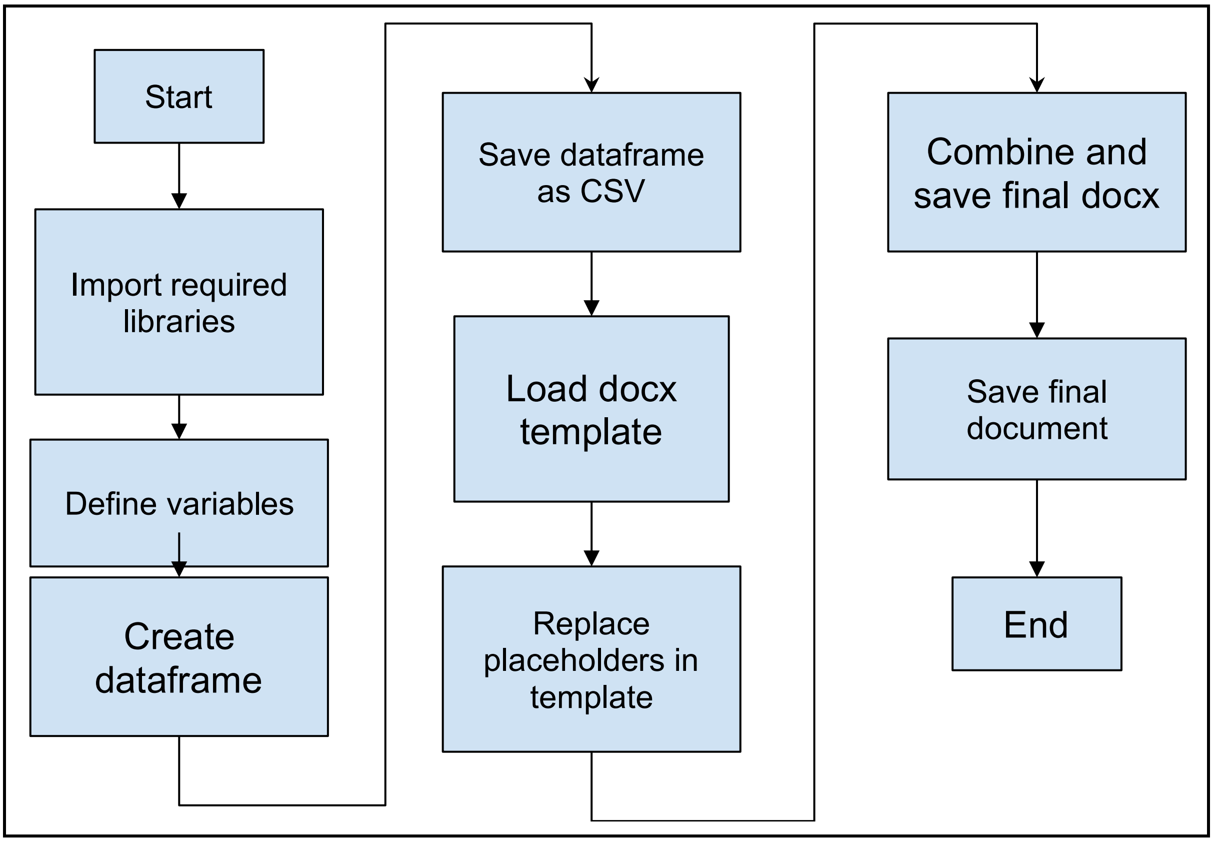

Figure 1: Flowchart of the code used

To automate the generation of random values for problem statements, there are two main outputs: (1) a spreadsheet file with the set number for each batch of randomly given problem values and the answers to the required values; and (2) a docx file with all the sets. An optional docx file can also be generated to make the answer for the specific problem set.

The following steps show how the code works. First, the program imports necessary libraries such as *numpy*, *pandas*, and *docx* which will be used to respectively handle the required numerical calculation, data manipulation and data formatting. Variables for randomized values of parameters (e.g. viscosity, density and temperature) were initialized. Ranges and arrays were used for this purpose.

A Python dataframe to store the set number, randomized values, and columns containing the answers to the questions for each set. Random values were populated using the *numpy.random.choice* function. A Word template with placeholders was used to provide the structure for the problem sets. A function that replaced placeholders with the corresponding values in the dataframe generated a unique problem set. This was repeated in a loop, for which the number of unique sets can be specified. Finally, all the problem sets were compiled into one docx file. All the program outputs were saved to a defined folder, which completed the workflow.

Implementation and Results

The project generated a total of 11 unique and customized problem sets. It produced four unique and customized problem sets for a chemical engineering calculations class, five for a momentum transfer class, and two for the separation processes class. The table that follows describes the topics explored and assessed using the bespoke problem sets.

Each course's 3-hour computational laboratory periods included these problem sets as formative assignments. There was an effort to make sure the problem set could realistically be completed during the scheduled meeting. Problem sets were distributed in a variety of ways. When in-person meetings were scheduled, the instructor printed the problem sets and handed them out to students. Students also had the option to request electronic copies. When in-person meetings were not feasible, individual copies of problem sets were sent as email file attachments to students using Google Developer tools or Microsoft Power Automate. Electronic copies of problem sets were also available via LMS such as MS Teams, Google Classroom and Moodle.

About half an hour before the computational lab session ended, students received personalized solutions to their problem sets and were asked to consider what they had done right or wrong. To successfully pass the course, students had to submit all the problem sets assigned to them. During the lab period, the instructor helped students go over their calculations through a guided approach. When students showed their solution, the instructor commented on whether it was correct. If it was not correct, the instructor would ask why they did it that way and would suggest other methods to arrive at the correct answer. This method encouraged students to make mistakes and coached them on how to improve their accuracy and speed.

At the end of the lab period, students have an informed perspective of the limits of their own abilities, the instructor has a clear role in helping the student achieve learning goals as a mentor and the learning process over-all is more encouraging to a growth mindset.

Table 4. Topics covered in each course by the individualized/bespoke problem sets

Chemical Engineering Calculations	Momentum Transfer	Separation Processes
1 - Units and Dimensional Analysis 2 - Matrices in Material Balances	1 - Units and Dimensional Analysis 2 - Pressure and Fluid Statics 3 - Newton’s Law of Viscosity	1 - Review of Mass Balances in Separation Processes 2 - Single Stage Leaching

3 - Material Balances in Multiple Units 4 - Material Balances in Unit Operations	4 - Continuity Equation and Frictional Losses in Pipes 5 - Bernoulli Equation and Mechanical Energy Balances	and Liquid-liquid Extraction

Since each student was assigned unique values for their problem, they had to really figure out for themselves what the answer was. Although they could discuss with peers how to do a certain problem, the actual implementation of the problem-solving technique individually was important to get the answer specific for their set. This highlights authentic engagement with the problem set material.

What follows are samples of the questions generated by the program. Questions come from the momentum course. Problem statements with unique set variable values and answers generated were the basis for individualization of the project.

The process for how to convert a sample question to a Python code block is shown below:

1. Originally, the problem as it appears in the textbook was
   2.14. An oil-water mixture from a pilot-plant reactor is separated in a horizontal decanter 0.6 m in diameter and 3 m long. The residence time needed in the decanter is found to be 20 minutes. (a) If a large unit is designed to handle 12 times the flow rate, what would be the dimensions of the large decanter?

2. In a template docx file, the problem was typed as:
   An oil-water mixture from a pilot-plant reactor is separated in a horizontal decanter {{var_e1_rand}} m in diameter and {{var_e2_rand}} m long. The residence time needed in the decanter is found to be {{var_e3_rand}} minutes. (a) If a large unit is designed to handle {{var_e4_rand}} times the flow rate, what would be the dimensions of the large decanter?

3. In the Python code, the following range of values were used. The set numbers were randomized with a range from 1 to 50:
   ```
   var_e1_range = np.linspace(0.5, 1.2, 7)
   var_e2_range = range(1,5,1)
   var_e3_range = range(15,25,1)
   var_e4_range = range(8,15,1)
   ```

   The conversion from *var_ex_range* to *var_ex_rand* was done using np.random.choice() function.

4. The Python function used to calculate and return the new diameter and length of the tank (d2, L2)

   ```
   def prob5(e1,e2,e4):
   V1 = (np.pi*(e1/2)**2)*e2
   V2 = e4*V1
   ```

```
k = e1/(2*e2)
r2 = np.cbrt((V2*k)/np.pi)
d2 = 2*r2
L2 = r2/k
return d2,L2
```

5. The values for d2 and L2 were fed to another section of the code that generated the unique answers for each set.

6. During process (5), placeholder values in the template file were replaced and the newly generated files contained the question statements and answers, of which samples are presented.

Table 5. Sample questions from a chemical engineering calculations problem set activity. (The problem was adapted from the textbook on Unit Operations by Warren L. McCabe [18])

Set No	Question Statements	Answers
4	An oil-water mixture from a pilot-plant reactor is separated in a horizontal decanter, measuring 0.5 m in diameter and 4.0 m in length, separates an oil-water mixture from a pilot-plant reactor. The residence time needed in the decanter is found to be 22.0 minutes. (a) If a large unit is designed to handle 14.0 times the flow rate, what would be the dimensions of the large decanter?	Problem 5: • The required diameter is 1.205 m. • The required length is 9.641 m.
7	An oil-water mixture from a pilot-plant reactor is separated in a horizontal decanter 0.5 m in diameter and 4.0 m long. The residence time needed in the decanter is found to be 21.0 minutes. (a) If a large unit is designed to handle 10.0 times the flow rate, what would be the dimensions of the large decanter?	Problem 5: • The required diameter is 1.077 m. • The required length is 8.618 m.

Table 5 continued. Sample questions from a chemical engineering calculations problem set activity. (The problem was adapted from the textbook on Unit Operations by Warren L. McCabe [18])

34	An oil-water mixture from a pilot-plant reactor is separated in a horizontal decanter 1.0 m in diameter and 2.0 m long. The residence time needed in the decanter is	Problem 5: • The required diameter is 2.496 m. • The required length is

	found to be 21.0 minutes. (a) If a large unit is designed to handle 8.0 times the flow rate, what would be the dimensions of the large decanter?	4.16 m.

Discussion

Students' Perception of Acceptability of the Approach to Learning
A total of 24 students responded (from a total of 130 students) to an invitation to answer a voluntary online survey on their attitudes and perceptions of personalized problem sets. The exact distribution of these students among courses was not determined in the study. They were asked to rate it on the following scale: 1: strongly disagree, 2: disagree, 3: neutral, 4: agree, and 5: strongly agree. The following table shows the averages from each question asked. There were four (4) key areas assessed, which include (1) content and difficulty, (2) clarity and structure, (3) learning impact and (4) overall satisfaction.

The table that follows contains the survey items given to the students.

Table 6. Questions and their associated themes in the survey

THEME/ Question	QUESTION
Content and Difficulty	
Q1	The problem set was relevant to the course topics.
Q2	The difficulty level of the problems was appropriate for my current knowledge.
Q3	The problem set challenged me to think critically and apply concepts.
Q4	The problems in the set were realistic and connected to real-world applications.
Clarity and Structure	
Q5	The instructions for each problem were clear and easy to understand.
Q6	The structure and flow of questions were logical.
Q7	I was able to follow the problem-solving process without confusion.
Q8	The provided information was sufficient to solve each problem.
Learning Impact	
Q9	The problem set helped me reinforce my understanding of course material.

Q10	Completing the problem set increased my confidence in this subject area.
Q11	The problem set highlighted areas where I needed additional study.
Q12	I feel more prepared for future assignments and exams as a result of completing this problem set.
Overall Satisfaction	
Q13	I am satisfied with the overall quality of the problem set.
Q14	I would like similar problem sets in future assignments.
Q15	The problem set met my expectations for this course level.
Q16	I would recommend this problem set as a valuable learning tool.

Analysis

Content and difficulty. An average score of 3.85 indicates a generally positive reception to this approach. Particularly for Q1 (4.33) and Q4 (4.33), a strong alignment with course topics and real-world relevance suggests students agreed that problems added were contextually appropriate overall. However, there were concerns with the difficulty and critical thinking level of the problems Q2 (2.83) and Q3 (3.92). This may indicate that the students feel that some of the problems may be too difficult for their current level or ability. While it may not be possible to determine with absolute certainty if Q2 results indicated the problem set was too easy or too difficult based on the numerical data alone, a future study could explore this as another item in the questionnaire. However, based on anecdotal feedback from students while implementing this method, the consensus seemed to coalesce on the perception that the difficulty of the problems depended on the nature of the task for each problem. For “plug-and-chug” problems in courses like momentum transfer and chemical engineering calculations, students seemed to report average difficulty, while for more complex problems, such as the design of LLE and distillation columns, students were more perplexed and required more frequent assistance from the instructor.

Clarity and structure. The average for this area was 3.15, signalling a need to improve this area. While the clarity of instruction (Q5: 3.38) and the logical arrangement of questions (Q6: 3.46) did indicate good results, there is still inconsistency that may need to be improved in the future. Because Q7 (2.79) and Q8 (2.96) scored the lowest, insufficient information and/or problem-solving processes which were not clearly explained could also be another focus of improvements in successive implementations.

Learning Impact. An average of 3.57 for this area indicates moderate effectiveness, however there are some nuances that need analysis. Reinforcement of the course material (Q9: 3.58), increasing confidence (Q19: 3.58) were positively received. However, a low score for Q12 (3.13) may suggest an opening for preparing students for other types of assessments.

Overall, students felt satisfied with problem set quality (Q14: 3.92) and were in agreement that the activity did meet its course-level expectations (Q15: 4.04). Students also saw value in recommending future problem sets (Q14: 3.92) and in endorsing it as a learning tool (Q16: 4.17).

Table 7. Summary of the survey results

THEME/ Question	AVERAGE		THEME/ Question	AVERAGE
Content and Difficulty	**3.85**		Learning Impact	**3.57**
Q1	4.33		Q9	3.58
Q2	2.83		Q10	3.58
Q3	3.92		Q11	4
Q4	4.33		Q12	3.13
Clarity and Structure	**3.15**		Overall Satisfaction	**3.93**
Q5	3.38		Q13	3.58
Q6	3.46		Q14	3.92
Q7	2.79		Q15	4.04
Q8	2.96		Q16	4.17

The effect of this intervention on the improvement of students' abilities on specific topics and learning objectives were not considered due to time and logistical constraints.

Conclusion

This work, although in its current form it may be considered simple, has the potential to provide every chemical engineering student a personalized learning experience that seeks to optimize both the students' and instructor/professor's time and resources.

The use of Python programming to generate individualized problem sets is a technique worth exploration and consideration by engineering faculty.

It's potential for a widescale implementation through an automated process via LMS integration or other methods could provide a way to increase the scalability of the project. For now, it can only change problem set values, but future iterations can consider other aspects of students' abilities and incorporate them into the generation of problem sets. For example, if a student has difficulties understanding the process for solving a certain problem, then the instructor can provide multiple versions with different given values to help the student practice the process. This may be helpful for particularly long, cumbersome or multi-step problems.

Future research work should focus on measuring the short and long-term impact of individualized problem sets utilizing AI and similar types of assessment. Specifically, it could focus on determining course and learning outcome specific improvements using a pretest/post-test quasi-experimental design.

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