

**Enhancing Student Learning in General Chemistry  
Using AI-assisted Customized Scaffolded Worksheets**

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As a chemistry educator, I have sought ways to enhance student engagement and academic performance. In my quest to foster deeper engagement and elevate academic performance, integration of AI-generated, scaffolded worksheets using ChatGPT (version 3.5) into a general chemistry curriculum represents an innovative pedagogical strategy. This fusion acknowledges the diverse learning styles and educational backgrounds of students, as supported by AI-Roomy's (2023) work on learning styles and their impact on GPA, and Yadav and Shukla's (2021) comprehensive literature review. The scaffolded method, highlighted by Barnard and colleagues (2021) for its capacity to guide students through complex problem-solving, has been enhanced by the efficiency and adaptability of AI. These AI-facilitated worksheets bring efficiency and uphold the evidence-supported benefits of scaffolded worksheets (Afalo, 2018; Cazan, 2022; Hmelo-Silver et al., 2007).

Inspired by the efficient potential of AI (Venkatasubramanian, 2018), integrating ChatGPT within chemistry education enhances traditional tools with timely customization (Fahimirad, 2018). By diversifying worksheet formats, we make use of the multidisciplinary opportunities of AI (Dwivedi et al., 2023) and address varied learning needs (Javaid et al., 2023). Research on AI in assessments further corroborates the effectiveness of these smart learning environments (Maestrales et al., 2023; Wang et al., 2023; Zhai, 2021). The unique power of these AI-crafted resources lies in their ability to deconstruct problems into simpler steps, meeting the learners at their current baseline of chemistry knowledge. Traditional word problems present information in a single block of text that students decipher and solve independently. However, using AI for

scaffolding takes it a step forward in personalization and ensuring that every student can navigate the coursework from their starting point. The adoption of these innovative tools has been encouraging, showing a positive trend in student performance on specific learning objectives.

### **AI-Assisted Scaffolding Worksheet Creation**

To develop my own scaffolded worksheets for my General Chemistry course, my initial step was to carefully select problems aligned with the Student Learning Objectives (SLOs). These problems are solved during the lecture and recitation sections. For instance, in designing a worksheet on Stoichiometry, the process begins with a specific instruction to ChatGPT. The AI responds by crafting an initial worksheet that introduces the fundamental concepts. Subsequent prompts evolve in complexity, leading students towards performing more intricate tasks like calculating stoichiometric yields. In addition, ChatGPT can tailor worksheet designs to specific student needs. It can also generate the final problem to be solved.

The items provided in the Appendix illustrate the ease of using ChatGPT and how it allows for real-time adjustments. When students struggled with understanding molar ratios in a lecture, I prompted ChatGPT to generate additional, tailored worksheets with digestible segments and a sequence of additional guided steps to make the topic more accessible. Feedback from students indicated specific preferences; some favored a tabular format that organizes information clearly, while others found worksheets consisting solely of prompts to be more conducive to their learning (Worksheets 2 and 3). Further, Worksheet 2 was created in mere seconds using the tool while the more traditional scaffolded worksheet format shown in Worksheet 3 had more generalized prompts. The flexibility and efficiency afforded by this AI-assisted process allows me to respond swiftly to the unique dynamics of student learning observed during class or individual consultations. I can use ChatGPT to produce customized content targeting specific difficulties or misconceptions. This ensures that each student, regardless of their starting point, is provided with the resources and support necessary to master the content.

While traditional scaffolded worksheets that systematically unfold concepts have been effective, ChatGPT brings a new dimension of fluidity and personalization. It saves valuable time,

allowing me to focus on direct student engagement and the nuances of individual learning journeys. This progressive complexity deepens comprehension and enhances student confidence. I encourage students to take ownership of their learning by crafting their own lesson plans and examples that stimulate their creativity in problem-solving. If a student encounters difficulties with a worksheet, initial interventions include targeted feedback and one-on-one discussions to identify specific areas of struggle. The scaffolded worksheets clarify each calculation step, fostering independence and empowering students to tackle problems by explicit scaffolding, yet still upholding the academic rigor required at the college level.

### **Study Methodology**

During Fall 2022, I engaged in my traditional teaching mode, which served as the baseline for my analysis. In this mode, word problems were delivered in extensive text blocks with no targeted guidance or adaptation throughout the semester. I first explored the application of ChatGPT in my Spring 2023 class, but without a specific plan in place regarding worksheet development. I presented these ChatGPT generated worksheets to students and noticed an increase in student engagement levels and concept understanding.

Based on this anecdotal evidence, I decided to investigate further the AI-assisted scaffolding approach in Fall 2023 by comparing student performance to that of students in Fall 2022 (baseline) and Spring 2023 (pilot). During Fall 2023, I again provided students with ChatGPT-generated worksheets as described above, but with greater planning on how the scaffolding should occur. Students in all three semesters were tested on key SLOs in my General Chemistry courses with a 10-point quiz for each SLO (elemental analysis, limiting reactant and percent yield, simple gas laws, ideal gas law, thermochemistry). I calculated an average score across the five learning objectives for each student, and then compared the students' average scores between Fall 2022 (baseline), Spring 2023 (pilot), and Fall 2023 (intervention).

Table 1 summarizes the difference in student quiz scores across the five concepts and overall for the different cohorts. Though inferential statistics did not indicate significant differences between Fall 2022, Spring 2023, and Fall 2023 average quiz scores, a trend towards

increased student quiz scores is evident, with a difference of up to 3.5 points between baseline and full intervention (limiting reactant and percent yield).

**Table 1**

*Semester-Based Quiz Scores on Select Student Learning Objectives*

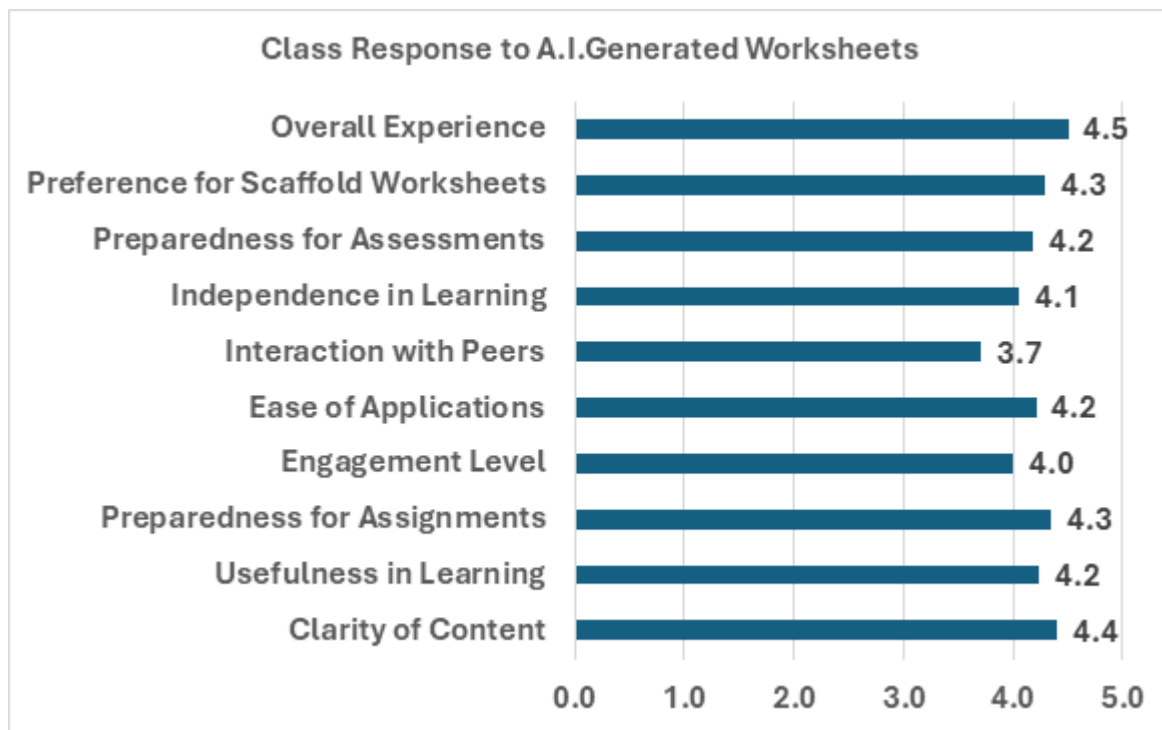
<b>Student Learning Objectives</b>	<b>Fall 2022</b>	<b>Spring 2023</b>	<b>Fall 2023</b>
Elemental Analysis	6.6	7.0	7.5
Limiting Reactant & % Yield	5.5	7.0	9.0
Simple Gas Laws	8.3	8.2	8.5
Ideal Gas Law	8.2	8.2	8.5
Thermochemistry	6.7	7.7	8.0
Average	7.1	7.6	8.3

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In evaluating the impact of AI-generated, scaffolded worksheets, it was important to consider the learners' perspectives. To this end, I administered a survey at the conclusion of Fall 2023, inviting students to reflect on their experience with these problem-solving tools (Figure 1). The responses are measured on a Likert scale, with ratings from 0 to 5 and higher values indicating more positive student feedback. Clarity of Content received the highest approval ( $M = 4.4$ ), indicating that students found the content delivered through these worksheets to be clear and understandable. Preference for Scaffold Worksheets and Preparedness for Assignments also scored highly ( $M = 4.3$ ), suggesting that students appreciated the structure provided by the worksheets and felt more prepared for assignments. Overall Experience Rating ( $M = 4.5$ ) indicates a broad support of this approach.

**Figure 1**

*Student Ratings on Effectiveness of AI-Generated Scaffolded Worksheets*



### **Conclusion**

This shift from traditional word problems to AI-assisted worksheets had a positive impact on both student learning outcomes and perceptions of value for the learning experience. Average quiz scores on all SLOs trended higher when AI-generated worksheets were used. Students rated the use of these worksheets positively across a number of specific qualities. Thus, this change in pedagogy reinforces AI's potential to complement established educational strategies (Javaid, 2023).

Using AI enriches the existing framework by providing enhancements to streamline certain teaching aspects while allowing educators to focus more on fostering critical thinking and personalized engagement. AI-generated scaffolded worksheets are innovative as they save the instructor time and allow for an individualized learning environment. The use of AI allows for the customization of content to fit the learner's current understanding, providing different levels of

difficulty and various types of scaffolding to support individual learning paths (Al-Roomy, 2023), ultimately promoting greater critical thinking.

These findings support the potential of AI, specifically ChatGPT, in augmenting traditional educational practices with a degree of customization that may extend beyond previous methods. By offering a more tailored approach to problem-solving, these technologies appear to resonate well with students' varied learning styles and allow for maintaining academic rigor at the college level. Our dedication to educational innovation extends beyond merely seeking to improve grades. It's about enhancing the learning experience for all students by broadening the available toolkit of pedagogical practices to incorporate AI-assisted tools.

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## Appendix

Sample Prompts for Generating a Stoichiometry Worksheet Using ChatGPT-3.5.



**You**

Create Reaction Stoichiometry, mass to mass conversions worksheet



**ChatGPT**

Sure, here's a worksheet on reaction stoichiometry and mass-to-mass conversion worksheet is designed to help students practice and understand the concept of s which involves the quantitative relationships between reactants and products in a reaction.

### Reaction Stoichiometry and Mass-to-Mass Conversions Worksheet

**Name:** \_\_\_\_\_

**Date:** \_\_\_\_\_

#### Instructions:

1. Balance the chemical equations if they are not already balanced.
2. Use the balanced equations to solve the stoichiometry problems.
3. Show all your work and include units in your calculations.

#### Problem 1:



Balance the following chemical equation:

Message ChatGPT...



### Worksheet 2: Reaction stoichiometry and Mass to Mass conversions

#### Problem 1: Mass-to-Mass Conversion for the Combustion of Methane (CH<sub>4</sub>)

Given that 18.04 grams of methane (CH<sub>4</sub>) is burned completely in the presence of excess oxygen, calculate the mass of carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O) produced.



Step	Description	Calculation	Result
1	Balanced Equation		
2	Calculate Molar Mass of CH <sub>4</sub>	Molar mass of CH <sub>4</sub> = _____	_____ g/mol
3	Calculate Moles of CH <sub>4</sub>	Moles of CH <sub>4</sub> = Mass (grams) / Molar Mass	Moles of CH <sub>4</sub> = _____ mol
4	Use Stoichiometry to Find Moles of Products	Moles of CO <sub>2</sub> = _____	Moles of CO <sub>2</sub> = _____ mol
		Moles of H <sub>2</sub> O = _____	Moles of H <sub>2</sub> O = _____ mol
5	Calculate Molar Mass of Products	Molar mass of CO <sub>2</sub> = _____ g/mol Molar mass of H <sub>2</sub> O = _____ g/mol	
	Calculate Mass of Products	Mass of CO <sub>2</sub> = Moles of CO <sub>2</sub> * Molar Mass of CO <sub>2</sub>	Mass of CO <sub>2</sub> = _____ grams
		Mass of H <sub>2</sub> O = Moles of H <sub>2</sub> O * Molar Mass of H <sub>2</sub> O	Mass of H <sub>2</sub> O = _____ grams
6	Record the Results	Mass of CO <sub>2</sub> produced = _____ grams Mass of H <sub>2</sub> O produced = _____ grams	

When 18.04 grams of methane (CH<sub>4</sub>) are burned completely, they produce approximately \_\_\_\_\_ grams of CO<sub>2</sub> and \_\_\_\_\_ grams of H<sub>2</sub>O.

**Worksheet 3: Reaction stoichiometry and Mass to Mass conversions**

Given that 16.04 grams of methane (CH<sub>4</sub>) is burned completely in the presence of excess oxygen, calculate the mass of carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O) produced.



**Step 1:** Balance the given equation:

**Step 2:** Calculate the moles of methane (CH<sub>4</sub>):

**Step 3:** Use stoichiometry to calculate the moles of products carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O):

**Step 4:** Calculate the mass of the products carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O):

**Worksheet 4: Stoichiometry Calculations**  
**Limiting Reactant, Excess Reactant, Theoretical Yield, & % Yield.**

- 1) For the reaction between 1.2 g of hydrogen (H<sub>2</sub>) and 0.50 g of oxygen (O<sub>2</sub>), determine the limiting reactant, excess reactant, theoretical yield, the amount of excess reactant remaining & the % yield if 0.31 g of actual product was obtained.

**Step 1: Balance the Reaction:**      H<sub>2</sub>(g) + O<sub>2</sub>(g) → H<sub>2</sub>O(g)

**Step 2: Convert Grams to Moles**

To determine the moles of each reactant, we need to convert the given masses to moles using their respective molar masses.

Substance	Given Mass (g)	Molar Mass (g/mol)	Moles
H <sub>2</sub> (g)			
O <sub>2</sub> (g)			

**Step 3: Determine the Limiting Reactant**

To find the limiting reactant, we need to compare the moles of each reactant to the moles of product using the stoichiometric ratio in the balanced equation. Whichever reactant generates least moles of product will be the Limiting Reactant, while the other reactant will be the Excess Reactant.

Limiting Reactant: \_\_\_\_\_      Excess Reactant: \_\_\_\_\_

**Step 4: Calculate the Theoretical Yield**

The theoretical yield is the maximum amount of product that can be formed based on the limiting reactant.

Take the moles of the product formed by the limiting reactant from Step 3 and calculate the grams of product.

Theoretical Yield of product = \_\_\_\_\_ g.

**Step 5: Determine the % Yield.**

To find the % yield of product, take the theoretical yield of the product and divide by the actual mass of product (given in the problem).

$$\% \text{ Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100\%$$

## How to balance a chemical equation??

Learn to Balance Chemical Equations with ChatGPT

Welcome to an interactive learning session where you'll master the skill of balancing chemical equations! Here's what you need to do:

### 1. Introduction to Balancing Equations:

- Start by typing the prompt: "Balancing Chemical Equations."
- Carefully read the response you get, which will include an example, such as the formation of water ( $\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}$ ).
- Understand the process and logic behind the example given.

### 2. Step-by-Step Guide:

- Now, type: "Let's go through this step by step to find the solution."
- Go through the detailed example provided (e.g., combustion of methane).
- Make sure to grasp each step in the method for balancing the equation.

### 3. Dive into Organic Chemistry:

- Proceed by typing: "How do I balance organic chemical equations?"
- Study the response, which will outline steps specific to organic reactions.

### 4. Detailed Breakdown:

- For additional clarification, type: "Let's break this down step by step to find the solution."
- Follow along with the explanation, particularly for a combustion reaction, and make sure to understand the process.

### 5. Hands-On Practice:

- Have a separate sheet of paper ready for practice.
- Work through the examples provided by ChatGPT on paper. This will help reinforce your understanding and provide valuable practice.

Remember, this activity is designed to enhance your skills through practice and understanding. Don't rush; take your time to fully comprehend each step. Happy learning!

Complete all the above before we start the in-class activity.

*Have fun!*