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Work in Progress: Wrappers vs. Experts

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Introduction

Eighty-one students enrolled in a required, third-year reaction engineering course were the subjects for this investigation. The author was the instructor for that course and had taught it more than twenty-five times before this offering. During that span, four substantial pedagogical changes occurred. After those changes the effect of completing homework upon an average student's course score improved by a factor of 2.5 [1].

One of those pedagogical changes incorporated homework wrappers into assigned homework problems. Briefly, the homework wrappers asked the students to reflect upon their approach to solving the problem and their execution of the solution and then write a brief summary analysis. One of the research-based principles of "How Learning Works," is that "goal-directed practice, coupled with targeted feedback enhances the quality of students' learning" [2]. In the present study, the intended purposes of the wrappers were to lead student to self-generate feedback that was detailed and well-targeted and to alter the students' goals for completing the homework. Specifically, the latter intended purpose was that students' goals when completing the homework would not be limited to obtaining the answer, but would include understanding how, more generally, to obtain an answer. This is another of the research-based principles of learning: "to develop mastery, students must acquire component skills, practice integrating them and *know when to apply what they have learned* (emphasis added)" [2].

The present investigation represents a formative assessment of the use of homework wrappers in this particular course. It seeks to identify shortcomings in the wrappers themselves and in their implementation to inform a decision whether to continue to attempt to develop them.

Methodology

The data for this study were collected during the Fall 2018 offering of the course. Over the span of the 15-week semester, the class met three times per week, excepting holidays, for a total of 42 meetings plus a final exam over 109 days. Each class meeting lasted 50 minutes; the class was "flipped," meaning that students watched video lectures prior to class with the majority of in-class time devoted to active learning. The student learning outcomes for the course are as follows:

1. Formulate an acceptable rate expression for a chemical reaction, appropriate to its anticipated end use.
2. Specify the experimental data needed to validate a rate expression and use available/resulting experimental data to do so.
3. Qualitatively predict and quantitatively calculate spatial and temporal variations of the flow rate, temperature, pressure and composition of an ideal batch, continuous flow stirred tank or plug flow reactor for a specified set of chemical reactions, and use the results for design or simulation purposes.
4. Recommend and quantitatively evaluate ideal reactor augmentations to enhance reactor yield, selectivity or other performance metrics.

5. Describe, formulate and implement alternative reactor models in situations where the ideal reactor models are not applicable.

Three of the five broad learning outcomes, items 2 – 4 above, for this course involve formulating a reactor model that includes mole balances, energy balances and a momentum balance. Students use the reactor models differently, depending upon the type of problem they are solving. Hence, students must be able to identify a problem's type and know the general approach for solving it. This study focused upon one problem type: kinetics data analysis (KDA, item 2 above).

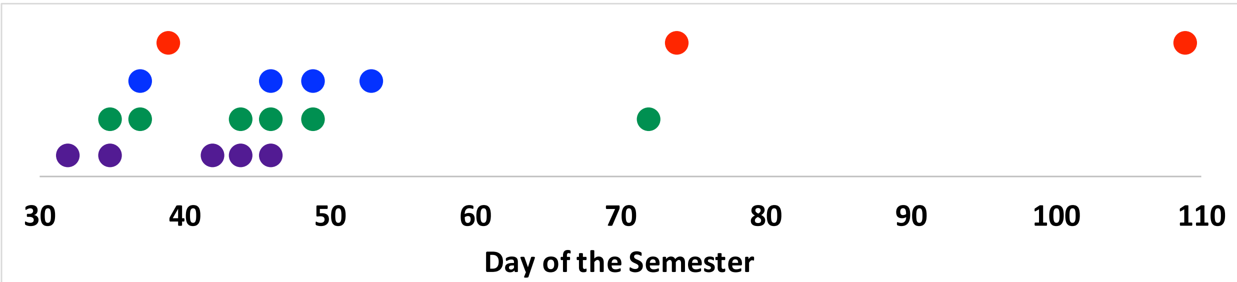

Figure 1. Project timeline for KDA problems. Purple dots indicate scaffolded (except day 46), in-class KDA problem solving, green dots indicate KDA practice problem submission, blue dots indicate homework wrapper (for the previous assigned practice) submission and red dots indicate exams that included one KDA problem.

As Figure 1 indicates, instruction on KDA began on day 32. The instructor first explicitly explained how to identify KDA problems.

> Kinetics data analysis problems will describe a reactor and how it was operated during experiments and it will present the resulting experimental data. The problem will identify one reaction that was being studied. The problem will ask you [the student] to find or test a rate expression to determine whether it is accurate and determine the best value for all kinetics parameters in the rate expression.

The instructor also presented a general, seven-step process for solving KDA problems.

1. Determine the reactor type and write one reactant or product mole balance.
2. Substitute the rate expression into the mole balance.
3. If the mole balance is a differential equation, solve it.
4. Convert the resulting equation into a linear equation, defining new variables as necessary.
5. For every experimental data point, calculate the values of the variables in the linear equation.
6. Fit a straight line to the resulting data.
7. Use the statistical and graphical results from fitting to decide whether the rate expression is sufficiently accurate.

Finally, during that first day, the students participated in a scaffolded, in-class KDA problem solving activity. This and all subsequent in-class activities incorporated the criteria for identification of KDA problems and the general process for solving them. Each in-class activity was followed by an assigned practice problem. After the assigned practice was turned in, the next assigned practice included a wrapper for the problem. It asked the students to reflect upon their approach to solving the problem and their execution of the solution and then write a brief summary analysis.

> Compare your [the student's] solution for [that homework problem] to the solution posted on [the course learning management system]. Identify each mistake you [the student] made (if any) and classify the reason for the mistake as (a) not identifying the problem as testing the validity of rate expression, (b) not determining the reactor type, (c) not correctly writing the reactor mole balance, (d) not correctly substituting the rate expression into the mole balance, (e) not integrating the mole balance (if necessary) (e) not linearizing the equation correctly, (f) not calculating the variables in the equation correctly for each data point, not fitting a straight line to the model correctly, (g) not analyzing the results of fitting correctly or (h) understood the concepts but made a math or programming error that caused the answer to be wrong. Write a brief (1-4 sentence) self-assessment based upon your analysis.

It should be noted that effort, not accuracy, was the basis for grading the homework problems. The instructor intended that the completion of the wrapper question should count for one of three points for the next problem, but a subsequent check revealed that the graders did not comply. Consequently, students did not receive a grade for homework wrappers.

After the course had ended, the instructor, a content expert, reviewed the students' KDA problem solutions and identified, using a code from Table 1, the first point where the student deviated from the general solution process. After completing the evaluation of all student KDA problem solutions, the instructor coded the students' KDA wrapper responses using the same codes. Again, only the first point of deviations from the general solution process that the student indicated in their wrapper was coded.

Once a student starts down a solution path that will not result in an answer to the problem, they might make other mistakes that are not included in the coding and they might miss additional steps that are listed in the coding because they are proceeding along an incorrect pathway. For this reason, only the first deviation from the general solution process was coded from the expert analysis and from the student analysis. The data set for the study comprised the expert coding for each KDA homework problem, coding for each student wrapper and the students' percentage scores on the three KDA exam questions. For the purposes of this study, a student's wrapper was deemed "accurate" if the first point of deviation indicated in the wrapper was the same as the first point of deviation identified by the expert. That is, if the code from the wrapper and the code from the expert were the same, the wrapper was considered "accurate." As such, an "accurate" wrapper correctly identifies *where* in the process the student first went wrong. It is left to the student, in reflecting upon their solution, to determine *why* they went wrong.

Table 1. Coding used for student problem solutions and wrapper responses.

Code	Error Identified
A	Problem type mis-identified or no idea how to proceed
B	Reactor type mis-identified
C	Mole balance incorrect or missing
C3	Rate expression not substituted correctly
E	Mole balance not integrated
E2	Integration error
F	Linearization incorrect
G	Variables in linearized equation not calculated correctly
H	Linear equation not fit correctly
I	Accuracy not assessed properly
J	Kinetics parameters not calculated correctly
ME	Math or programming error
NS	No specific mistake identified
NE	No error in the solution
NR	No response; student did not answer wrapper question

Results

As the timeline shows, one exam including a KDA problem occurred after the first wrapper while the other two exams with KDA problems took place many days after the last KDA problem wrapper. Using the first exam, Table 2 presents statistics related to the short-term effectiveness of the first wrapper; Tables 3 and 4 present completion and accuracy statistics, respectively, for the full set of wrappers.

Table 2. Completion and accuracy of the day 37 wrappers.

Student Group	Percent of All Students	Percent of Students Submitting Wrappers	Mean Score (%) on Day 39 KDA Exam Question
All	100	n.a.	62.4 ± 7.7
No Response to Wrapper	46.9	n.a	49.1 ± 11.2
Submitted Inaccurate Wrapper	27.2	51.6	61.6 ± 16.1
NS or ME Identified	18.5	34.9	
Submitted Accurate Wrapper	25.9	48.4	87.5 ± 7.2

Table 3. Wrapper completion summary.

Student Group	Percent of All Students	Mean Score (%) on Day 74 KDA Exam Question	Mean Score (%) on Day 109 KDA Exam Question
All	100	61.0 ± 6.5	68.7 ± 5.9
No Responses to Wrappers	12.3	36.7 ± 19.6	39.1 ± 22.3
Submitted 1 Wrapper	16.0	57.7 ± 20.5	65.1 ± 16.2
Submitted 2 Wrappers	17.3	56.2 ± 18.1	56.3 ± 20.0
Submitted 3 Wrappers	18.5	72.7 ± 12.8	78.7 ± 8.5
Submitted 4 Wrappers	35.8	67.1 ± 9.8	81.4 ± 4.7

Table 4. Wrapper accuracy summary.

Student Group	Percent of All Students	Mean Score (%) on Day 74 KDA Exam Question	Mean Score (%) on Day 109 KDA Exam Question
All	100	61.0 ± 6.5	68.7 ± 5.9
No Responses to Wrappers	12.3	36.7 ± 19.6	39.1 ± 22.3
0% Wrapper Accuracy	35.8	56.6 ± 11.5	60.9 ± 10.2
25% Wrapper Accuracy	5.0	63.3 ± 37.0	83.6 ± 5.7
33% Wrapper Accuracy	8.7	82.9 ± 14.0	83.7 ± 11.9
50% Wrapper Accuracy	18.5	62.2 ± 15.2	73.1 ± 12.1
67% Wrapper Accuracy	2.5	75.0 ± 317	94.3 ± 36.3
75% Wrapper Accuracy	7.5	72.2 ± 21.8	83.8 ± 14.8
100% Wrapper Accuracy	9.9	72.9 ± 27.5	87.5 ± 10.8

When considering only the first wrapper, Table 2, it is easy to break out the accurate, inaccurate and inaccurate with NS/NE wrappers and show completion rate and exam scores for each category. However, doing so for the full data set would lead to a much larger set of student groups (each of the last four rows in Table 3 would splint into 3 rows) with only a small number of students in each row. For this reason, no attempt was made to link overall completion to overall accuracy.

Discussion

Two observations stand out as particularly important. The first is that the no response rate was high. While 85.7% of all homework assignments were submitted, responses were received for only 61% of the KDA wrappers. A significant portion of this difference can be attributed to the problem being part of one assignment and the wrapper being part of the next assignment. If a student skipped one assignment, that would result in no response for two wrappers: one because the wrapper was skipped and a second because by skipping a problem, the student could not respond to the next wrapper. Clearly, if a means can be devised to package a problem solution and its wrapper as a single assignment, the response rate will approach the overall completion rate.

The second observation is that there is a high level of disagreement between the students' self-assessments and the expert's assessments. Table 4 effectively reports accuracy for per student. In order to be 100% accurate, a student must have submitted all four wrappers and they must have agreed with the expert. The table then shows that 9.9% of all students accomplished this. Similarly, to be 75% accurate, a student must have submitted all four wrappers and three of the four must have agreed with the expert. It is also possible to assess accuracy on a per wrapper basis. Considering only instances where both the solution and the wrapper were submitted, the students and the expert agreed only 43% of the time. There are a few factors that contribute to this low agreement rate.

It is apparent that in as many as 31% of the responses, the students did not make an earnest effort to identify their mistakes. Specifically, in 16% of the responses that did not agree with the expert, the students indicated they had made a math or programming error, but they did not identify what that error was. In another 15% of the responses that did not agree with the expert, the students' responses were non-specific. Most typically said something to the effect of "I didn't understand how to solve the problem, and I'll need to study harder." As noted above, the wrappers were not graded. The agreement rate might be improved by grading the wrappers and/or by providing feedback on them (or at least on the first few of them).

Another possible issue is that the wrappers are quite fine-grained. The generalized solution process for KDA problems has seven steps, but there are 15 different codes. An alternative implementation might replace the written reflection with something closer to the homework grading the students are used to. Specifically, the students might be asked to "grade" their own homework by drawing a circle around each mistake they made and labeling the circle with the step number that was incorrect or as ME (math/programming error).

The author believes that both the completion rate and the agreement rate can be improved by modifying the wrappers and their implementation as mentioned here. A superficial examination of Tables 2 through 4 might suggest that accurate completion of wrappers has a positive effect upon exam grades and non-response or inaccurate completion of wrappers results in lower grades. It is more likely, however, that students with higher completion and accuracy are also students who study more diligently and complete assigned problems more thoroughly. This could be the cause for both the higher exam scores and the higher wrapper completion/accuracy rates.

A high completion rate and high accuracy are expected to be necessary for the wrappers to be effective. A better measure of that effectiveness, however, may be the rate of recurrence of an error after it has been identified using a wrapper. The recurrence rate for identified and non-identified errors has also been studied in this project, but it is being reported separately. Briefly, while the numbers are small, the recurrence of identified errors was half that of non-identified errors.

On the basis of the present results, it has been deemed reasonable to refine the wrappers and their implementation as described here to see if the completion and agreement rates improve. The results, combined with a study of identified versus non-identified recurrence rates for a larger number of cases, will give a better indication of the usefulness and effectiveness of homework wrappers.

Summary

This formative assessment of the use of homework wrappers focused upon completion and agreement rate (accuracy). The observed rates are both lower than hoped for, but the study suggest ways that both the wrappers and their implementation might be improved.

References

[1] C. R. F. Lund, "Can Students Self-Generate Appropriately Targeted Feedback on Their Own Solutions in a Problem-Solving Context," in *ASEE Virtual Annual Conference*, 2020: ASEE, p. 17, doi: 10.18260/1-2--34256.

[2] Ambrose, S. A. et al. *How Learning Works: Seven Research-Based Principles for Smart Teaching*. The Jossey-Bass Higher and Adult Education Series. 2010, San Francisco: Jossey-Bass. 199pp.