Effects of Requiring Students to Write Abstracts for Homework Problem Solutions

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Abstract

This paper describes a one-semester study in which students in a course on material balances were required to write abstracts for homework problems. Students were assigned weekly homework assignments which consisted of problems assigned from the course textbook. Students completed the assignments in teams of three and submitted one solution per team. However, in addition, each individual student was required to write an abstract for each problem. In the abstracts, students summarized the purpose of the problem, the system under consideration, the known and unknown information and the solution procedure. There were two purposes to assigning the abstracts. First, it was hypothesized that requiring students to write about their problem solutions in a reflective way could foster a more thorough understanding of the processes being modeled, and instill in students a conscious recognition of effective problem-solving strategies. Second, it was hypothesized that the abstracts would provide an effective tool for assessing individual contributions to the team assignments. The authors present an assessment of the impact of the abstracts, specifically addressing the following question: Did students attain the learning objectives of the course more thoroughly than students in a previous cohort, who completed comparable homework problems in teams of the same size, but who were not required to write abstracts?

Introduction

The introductory chemical engineering course at most universities focuses on material and energy balances. Historically this course has had the reputation of being a conceptually demanding course that induces fear in many students[i]. One of the greatest challenges faced by many students is the solution of "word problems" which require the interpretation of text and its translation to a diagram and equations. Many students who get this far struggle to develop a systematic solution procedure – often they can solve simpler problems in an intuitive manner, but the utility of this approach has limitations when the problems become more complex. We observe that when students obtain a numerical result to a problem (regardless of their approach), they are so relieved that they consider it "solved", draw a box around the result, and move on without reflection. Students often complain that they can solve example problems in class when some guidance is given, but they flounder when they are left to solve a problem independently. One of the greatest challenges of teaching this course, therefore, is to teach students to apply problem solving strategies systematically. In this paper we explore the use of writing abstracts to encourage reflection with the intention of improving student learning, specifically with respect to parameterization of the process, application of principles, and development of solution procedure.

Writing Across the Curriculum

The literature consistently demonstrates that student learning is enhanced when students write about what they learn. Maharaj and Banta[ii] used four types of writing assignments (summaries, analogies, word problems and explanations) to promote students' understanding of course content and to increase the students' active role in the learning process. Sharp et al.[iii] propose several types of writing assignments that meet the needs of different learning styles to enhance learning. Felder and Brent[iv] designed a variety of writing assignments that enhance students' interest in course material and facilitate learning. Burrows et al.[v] showed that reflective journal enhances conceptual understanding and additionally improves learning of *content*. Korgel[vi] found that journal writing exercises can improve deep learning and creativity. In the Chemical Engineering Curriculum, Miller uses journal writing to foster the development of higher order thinking skills in a fluid mechanics course.[vii]

In sum, writing assignments can be used as a tool to instill in students a reflective approach to learning. The literature contains evidence that this does, or at least can, lead to improved student achievement of learning objectives. The next section discusses the specific writing assignment used in the current study, and the course in which it was introduced.

Material and Energy Balances

Strategies specifically for teaching material and energy balances have been the subject of several articles in the educational literature. In 1990, Felder observed that the drawing and labeling of a flow chart and its use in the systematic solution of a problem are critical to success in the course[i], and he describes a group-based Socratic approach to show (rather than tell) students how to work through a problem. Bullard and Felder [viii] describe the delivery of a material and energy balance course. In-class delivery included a variety of active learning strategies, and weekly homework assignments were completed by student teams in manner that met cooperative learning criteria. Textbook problems were often used with parts added to require reflection on the meaning of calculated results or speculation about the reason for differences between calculated and measured values[ix]. The effectiveness of these reflections in enhancing student learning was not explicitly evaluated.

Principles of Chemical Process course (ChE 201) is the first disciplinary course in Rowan University's chemical engineering curriculum. This two-credit hour course focuses on developing problem solving ability and applying the principles of conservation of mass. The class met twice per week (for a total of 215 minutes per week), and a variety of active learning strategies were employed in class as recommended by Bullard and Felder[viii, ix]. <u>Elementary Principles of Chemical Processes</u> (3rd ed.) by Felder and Russeau was the chosen textbook. Homework assignments were completed by student teams, with measures taken to ensure effective cooperative learning. In addition to handing in a copy of the team's solution to the homework problem, students were individually responsible for writing an abstract of each homework problem. The abstract verbally summarizes essential aspects of the problem: a description of the system, information given, unknowns, solution procedure and result. Writing abstracts provided the opportunity for students to reflect on a problem solution, and to organize and explain a systematic solution procedure even if the original result had been reached intuitively. It was anticipated that writing abstracts could help students achieve course objectives in several ways, including helping them to make connections between concepts, helping them to develop a systematic approach to solving problems, and helping them to recognize gaps in their own understanding of course concepts. A secondary purpose of the abstracts was to help gauge individual involvement in team assignments; a student who wasn't really contributing to the team would be unable to articulate how the team solved a problem. The following sections present efforts to assess the effectiveness of using the abstracts.

Experimental and Control Groups

In 2011, Principles of Chemical Processes I was taught in a single section, and 40 students completed the course. In 2012, the course was taught in two sections: section 1, with 24 students, was taught by the 2011 instructor, and section 2, with 27 students, was taught by an instructor who had never taught the course before. Since the 2011 cohort was not required to complete homework problem abstracts and the 2012 cohort was, the 2011 cohort is here used as a control group. Exams and homework assignments were common to the two sections in 2012. The instructors devised grading rubrics for the exams jointly and compared point values assigned for the most common errors to make grading consistent between the sections. Table 1 shows that while section 2 consistently scored higher, the differences in performance on the exams were usually small and never statistically significant.

	Section 1 – 24 students		Section 2 – 27 students	
	Mean	Std. Dev.	Mean	Std. Dev.
Exam 1	86.4	17.9	92.0	10.7
Exam 2	82.1	14.4	85.3	14.0
Exam 3	85.4	13.2	86.7	9.8
Exam 4	83.4	14.1	90.1	7.2
Final Exam	86.5	16.7	90.2	9.1

In 2011, homework assignments were completed and submitted in teams of 3. Typically, the assignments consisted of 5-6 problems per week, and comprised 10% of the course grade. In 2012, homework assignments were again completed and submitted in teams of 3, with both instructors assigning the same homework problems. In addition, each student submitted homework abstracts individually. The typical weekly assignment had one fewer problem than the corresponding assignment from the previous year to compensate for the added work of writing the abstracts. The homework again comprised 10% of the course grade, with the abstracts counting as one-third of the homework grade.

In 2011, the course had three exams, and the instructor noted that it was common for students to be surprised when they scored poorly on the first exam, which was worth 30% of the course grade. Consequently, in 2012, the course was structured with five exams, the first of which was early in the semester and worth 10% of the course grade. The intent was to give students feedback early in the semester on whether they were as proficient at solving problems on their own as they believed they were. Further, if they subsequently improved, the first exam would have relatively little impact on the final grade. While the authors feel this new course structuring was beneficial to the course, it also represents a major confounding factor in assessment of the impact of the homework abstracts. The next section presents evidence of improved student learning in the 2012 cohort, but the authors are unable to attribute it conclusively to the introduction of the abstracts.

Comparison of 2011 and 2012 Final Exams

The 2012 cohort earned an average score of 87% on the final exam, compared to 73% for the 2011 cohort. However, a simple comparison of the exam grades is not a valid assessment. Beyond the fact that they were different tests, we note that all exams in both years were comprehensive, but with an emphasis on topics covered since the most recent exam. Consequently, the scope of the final exam was different in the 5-exam course structure than in the 3-exam course structure. The authors identified a type of problem that was common to both exams and representative of the primary pedagogical goals of the course: problems that involved two independent material balances and also involved models of phase equilibrium (either VLE or LLE). Problems on either test that didn't meet this description were excluded from the assessment, providing a fair basis for direct comparison of the two cohorts.

The rubric shown in Table 1 was used to assess student solutions to problems. The rubric identifies four aspects of the problem solution: parameterization of the process, principles of mass balances, principles of phase equilibrium, and solution. In essence, the first three represent translation of the "word problem" into a set of model equations, and the fourth represents progressing from the equations to numerical answers. For each aspect of a problem, three levels of achievement were identified. The rubric was applied individually to each problem. As a result, the assessment data consist of 120 data points from 2011 (40 students, three problems each) and 102 data points from 2012 (51 students, two problems each). The results are summarized in Table 2. The 2012 cohort performed better on the final exam in all respects. While the difference between the cohorts for "Parameterization of Process" was not statistically significant, the differences between the cohorts for the other three aspects of problem solution were statistically significant to 95% confidence.

In addition, we note that the Rowan University Chemical Engineering program requires students to earn at least a C- in this course in order to progress to the next course. In 2011, eight of 40 students fell short of this threshold. In 2012, only one of 51 students earned lower than a C-. This student was in Section 1 and represented an outlier that had a noticeable effect on the means and standard deviations reported in Table 1, particularly on the final exam (40%).

Table 1: Rubric used to assess final exams.

	3	2	1
Parameterization of Process	Correct and complete interpretation of problem statement. Produces clear, accurate diagram and list of knowns and unknowns.	Broadly correct interpretation of problem statement, but overlooks or misunderstands one or two details.	Misunderstands or misrepresents the process being modeled in a fundamental way.
Application of Principles: Mass Balances	Writes mass balance equations that are completely accurate and sufficient in number to solve	Identifies relevant mass balance equations and approaches writing them in logical way,	Fails to apply mass balances, or writes mass balances that are haphazard and fundamentally

	problem.	but makes errors in execution, such as overlooking one term or confusing mass fraction with mole fraction.	unsound.
Application of Principles: Phase Equilibrium	Identifies all relevant phase equilibriums and writes an equation that accurately models each	Identifies relevant phase equilibriums and approaches modeling each in a logical way but makes errors in execution.	Models of phase equilibrium are missing or applied in a way that is haphazard and fundamentally sound.
Solution	Completes a solution that fully answers posed questions and is consistent with the model equations.	Progresses from model equations towards a solution in a logical manner, but makes minor errors.	Solution is incomplete or contains fundamental conceptual errors.

Table 2: Comparison of 2011 and 2012 final exam performance. Problem solutions for all students were scored from 1-3, with 3 being best.

Problem Attribute	2011 Mean	2011 Std. Dev.	2012 Mean	2012 Std. Dev.
Parameterization of Process	**2.73**	**0.56**	**2.89**	**0.34**
Application of Principles: Mass Balances	**2.33**	**0.81**	**2.81**	**0.48**
Application of Principles: Phase Equilibrium	**2.43**	**0.82**	**2.75**	**0.57**
Solution	**2.28**	**0.81**	**2.54**	**0.57**

Student Opinion of Homework Abstracts

At the end of the semester, a survey was administered and 47 of the 51 students in the course responded. The survey had nine questions, which students answered on a 1-5 scale that represented a continuum between "never" and "always," as well as open ended questions asking whether the abstracts should be kept as a feature of the course and what if anything should be changed. The responses to the first nine questions are summarized in Table 3. The data shown is aggregated for students in both sections, since there was no significant difference in the responses from the two sections.

The student perception, on the whole, was that the abstracts were only marginally useful:

- Only 3 students out of 47 reported that the process of writing abstracts "frequently" caused them to detect errors in their problem-solving process, and only 14 said the abstracts "sometimes" had this effect.
- 31 students (66%) said that the process of writing the abstracts was "almost never" or "never" helpful for producing a diagram or model equations for a problem, only 7 students (15%) said the abstracts were "frequently" or "always" helpful in this respect.
- On other questions regarding ways in which the abstracts might have benefitted students, such as helping them see connections between concepts, helping them "transfer and organize information," and helping them recognize patterns in solving problem strategies, the response was slightly more positive, but the mean responses were still below 3.0. "Sometimes" was the most common response to these questions.

The question "Does the process of explaining to someone else how to solve a problem change or enhance your own understanding of the problem solution?" was the first question in the survey. 72% of students answered "frequently" or "always" and an additional 19% answered "sometimes." This positive response, juxtaposed with the less favorable response to the other questions, suggests that a number of students recognize the pedagogical value of explaining to someone else how to solve a problem, but didn't consider the abstracts a necessary or effective vehicle for doing so. One possible explanation is that the activity of writing the abstracts was largely redundant for students whose teams were legitimately practicing collaborative learning. One student explained "If the student is getting help/working with his/her team then I think the abstracts aren't that important because the same process occurs in the team." While no other students expressed this sentiment explicitly in the open-ended questions, almost half of students (21/47) reported that the abstracts were "frequently" or "always" similar to the content of team discussions of problems, and another 18 said "sometimes."

In the open-ended questions, 24 students (51%) gave an unambiguous recommendation that the abstracts not be kept as a feature of the course next year, 16 students (34%) gave a clear recommendation that they be kept, and the other 7 provided some thoughts but no clear recommendation. This comment was typical of the people who were opposed to continuing use of the abstracts:

"I personally found the abstracts to be a complete waste of time. I'd write up the problems, work hard on them, get an answer, understand the material, and then have to write an abstract on something I already did and understood."

Even students who had broadly positive opinions of the abstracts often felt that they took too much time, and/or that they should have been a more important portion of the course grade. Representative comments include:

"I think writing abstracts definitely helps reinforce some concepts, but it takes up too much time to write a good one for each problem. For me, writing abstracts was just doing each problem twice."

"They should be kept only if they are worth a greater portion of the homework grade."

"It felt like a waste of time since they weren't graded."

"Abstracts could be written only for the more challenging problems, sometimes it was repetitive."

"Sometimes they're good. Sometimes they take more time to write than doing the actual HW problems."

"I think the abstracts should be worth a percentage of the grade (ex. 5%). They took a lot of time and effort to do correctly."

Table 3: Response to survey on homework abstracts. For all questions, responses were defined as 1=never, 2=almost never, 3=sometimes, 4=frequently, 5=always

	1	2	3	4	5	Average
1. Does the process of explaining to someone else how to solve a problem change or enhance your own understanding of the problem solution?	1	3	9	21	13	3.89
2. Did writing abstracts for homework solutions change or enhance your understanding of why you approached the problem a certain way?	11	12	14	10	0	2.49
3. Did the act of writing abstracts for homework solutions ever cause you to realize you had made an error in the problem solution?	14	16	14	3	0	2.13
4. Was the content of your homework solution abstracts similar to the content of discussions among your teammates about how to solve the problem?	5	3	18	17	4	3.26
5. Did writing abstracts help you to translate a problem statement into a diagram and/or equations?	19	12	9	6	1	2.11
6. Did writing abstracts help you to see patterns and understand methods in solving problems?	9	11	11	14	2	2.77
7. Did writing abstracts help you to make connections between different concepts?	11	6	20	8	2	2.66
8. Did writing abstracts help you to transfer and organize information?	11	6	16	12	2	2.74
9. Did writing abstracts help you remember how to apply information/concepts so that you could use this information to solve future problems?	10	7	17	12	1	2.72

Summary and Conclusion

Students in a material balance course completed homework problems in teams, but each student was also required to write an abstract explaining the solution to each problem. The intent of the requirement was that the process of writing abstracts would foster reflection in students, and help them to establish a systematic and repeatable approach to solving problems. The abstracts were not particularly popular with students. At least half of students favored eliminating the requirement in future offerings of the course, and even those who recommended keeping it thought refinements were needed.

Recommendations

Despite this unpopularity, there are indications that writing abstracts lead to increased student learning, as the 2012 cohort performed significantly better than the 2011 cohort which did not write homework abstracts. This improvement cannot be attributed conclusively to the introduction of homework abstracts because other modifications were also made to the course in 2012. But the authors feel that there is still a strong argument in favor of abstracts having some positive impact on learning due to the consistent results in the literature about the benefits of write-to-learn assignments, in conjunction with the improved student learning outcomes for the cohort who wrote abstracts. It is possible that the abstracts are like "bad tasting medicine" that has a benefit despite the patient's reluctance to use it. Considering the students' comments, we would recommend a few changes before trying this assignment again. The comments indicate that the students did not see the benefits, that the assignments were onerous, and that they did not count toward enough of the grade. Perhaps we could increase the value of the assignments by reducing the quantity and selecting only key problems for which abstracts are required. In such a case, the problems selected for writing abstracts would be problems that were *not* assigned in 2012, to prevent sharing of solutions across years. As another improvement, we could make the grade weighting more clear. The student feedback indicated their perception that abstracts were not graded, but in reality they were graded as done or not-done, and they counted for 1/3 of the homework grade. We just did not take off points for the quality of the writing, and we did not deduct again for errors that had been made on the traditional homework. In addition, we would change the nature of the abstract assignment to include a couple of questions targeted at a specific problem; these questions would be designed to foster higher order thinking that would get the students to explore, analyze, synthesize and make connections between old and new knowledge. Finally, we could experiment with the effect of assigning students to write abstracts before, rather than after, completing the full solution of problems.

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