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A Model for Quantifying Student Learning Via Repeated Writing Assignments and Discussions

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In this study, we assessed small and large group discussions and repeated writing assignments with the intent to objectively measure the values of these learning pedagogies. We crafted a model where students researched a question, formulated a written answer, discussed it with their peers, and revised their answers. Then, we did it with repetition to provide practice and experience. Improvements in understanding due to discussions were measured at 12%, while improvements of writing skills increased 29% during the course of the semester. Because we carefully structured the methodology and intent of the assignments, we suggest the assessment data could be used for quantitatively measuring student learning.

Active techniques, such as discussion, writing, interactive labs, and collaborative exchange, have been lauded as a way to increase learning in the classroom, particularly when compared to more passive approaches such as lecture (Davis, 1993; Lawrenz, Huffman, & Appledoom, 2005; McKeachie, 1999; Meyers & Jones, 1993; Wurdinger, 2005). Active techniques have been well documented, providing instructors with a variety of options and guidance tips that can be tailored to unique classroom situations. In many cases, the students take control of the learning process (e.g., discussions, laboratory experiential activities, group assignments, game simulation, etc.) with seemingly positive results (Clark & Smith, 2004; Lauer, 2000; 2005; Orvis & Orvis, 2005; Sutherland & Bonwell, 1996). Despite this plethora of methodologies, the inferred value of active learning is difficult to assess and may not be readily apparent from a single activity or event (Stiggins, 1995).

A lively and productive class discussion on evolution, for example, may be beneficial to students, and many identify this type of activity as being an effective learning tool (Gullette, 1992; McKeachie, 1999; Meyers & Jones, 1993; National Research Council, 1996). We also believe discussion structures conversations and enables participants to present, understand, compare, examine, and understand both similar and variant issues (Pestel, 1997; Wilen & White, 1991), promoting a higher level of thinking (Gall, 1985). Gall and Gall (1990) indicate the learning outcomes of classroom discussion include mastery of content material and an increase in problem solving skills. But, how much more do students learn using this pedagogy compared to a lecture? Moreover, how might it compare to alternative active learning techniques that have been shown to have merit? Answers to these questions rely on the ability to assess the activity without confounding interference. Stiggins (1995) and Black, Harrison, Lee, Marshall and Williams (2004) provide approaches and guidance that should be followed if assessment for measuring achievement is the goal.

The deficiency in science writing skills by students has been documented by a number of science educators (Jerde & Taper, 2004; Koprowski, 1997; Moore, 1994; Rice, 1998; Tessier, 2006) with the composite suggestion that writing can be improved with guidance, feedback, and repetition. If identifying compositional/grammatical areas that need improvement coupled with repeated assignments does improve technical writing skill, why is this technique not commonplace in the classroom? We suspect the instructional effort needed for this approach is beyond the logistical abilities of most teachers given their other course duties, unless the course is classified as writing intensive. However, writing can also be used as an active technique for learning content material (Moore, 1993, 1994). The act of putting thoughts on paper forces students to clarify ideas, for example, by postulating hypotheses, organizing facts, etc. in a way that is rarely possible otherwise (Feldman, Anderson, & Mangurian, 2001). Thus, the act of writing in the classroom may produce duel benefits to the student that most instructors cannot otherwise duplicate.

In this study, we assessed the value of writing assignments and small and large group discussions from the perspective of both the instructor and the students. We did so with the intention to assess the value of both writing and discussion activities quantitatively. Three questions emerged: (a) Were there improvements in technical writing skills using repeated writing assignments with detailed feedback?; (b) What was the value of discussion in the classroom for learning biology?; and (c) Did the student's attitudes change pre/post about technical writing and discussion, and did they feel it aided their learning of biology knowledge and increase their writing skills? Although the pedagogy in this study was biological in nature, the methods and scope of our model could easily be applied to any discipline.

Methods

Classroom

The students evaluated in the study were enrolled in a Department of Biology course (Limnology; 3 credit hours) at Ball State University and included junior, senior, and graduate students studying biology or a related discipline. The course met three times a week: two 50 minute lectures and one 110 minute lab for 15 weeks. During the first week, students were provided a syllabus that explained the course objectives, with specific emphasis and clarification on the writing assignments and our reasoning for them. Although this study was conducted in an upper division course in a four year university, the authors feel it could provide a model (Figure 1) that transcends grade and could easily be used in middle school, high school, or first year college courses.

Every two weeks a writing assignment was given (for a total of six throughout the course). Each followed a similar format. Assignments emphasized manuscript evaluations, concept evaluation, or textbook reading (examples in Table 1) where the student would need to apply, analyze, or synthesize information, typically identified as a higher-order cognitive skill (Bloom, 1964; Lord & Baviskar, 2007) as advocated by Zoller (2000). Prior to giving an assignment, searches were done on the Internet (e.g., Google®) to determine whether students could find answers they could use directly or peripherally. If so, the question was altered or eliminated to avoid the temptation of plagiarism following Gibelmen, Gelman, and Fast (1999). In general, the subject matter for the assignments was not discussed in previous lectures, and students were required to formulate answers based on individual scholarly pursuits. These answers were most often in the form of an argument, defending a point of view. This approach minimized plagiarism and mimicked the kind of rhetoric found in the "discussion" portion of scientific publications. Students were cautioned against collaboration, although we remained open to questions or clarifications at any time. Length was limited to 250 words and assignments were submitted electronically via email attachment prior to class time on the day it was due. A paper copy was also brought to class that was used for the day's discussion.

On the day assignments were due, students (N = 16) were placed into one of four groups with composition of the groups varying with each assignment. When the class began, students were asked to discuss their answers within their group. As the instructors, we would interact with the groups, but only in a probing way to help students clarify or collaborate their answers. Care was taken to not provide the students with our response or interpretation of the assignment. Following this period, individual groups would present their answers to the remainder of the class, initiating a whole class discussion. When this discussion was complete, we would provide comments and thoughts verbally, summarizing the information provided by the students and correcting any misconceptions. At the end of the class, students were given the option of re-writing their assignments based on what they learned from the discussion.

A rubric (Table 2) was used to assess student performance and was divided into two parts: assessment of grammar/writing style (10 points) and biology content understanding (10 points). Evaluation and commentary were additionally provided on the assignments using the "Track Changes" and "Insert Comment" functions on Microsoft® Office Word 2003. Both positive aspects of the submissions and areas that needed improvement were identified. In addition, efforts were made to show how problem areas could be corrected. If a student re-wrote a paper based upon the class discussion, the student only saw and received the grade from the re-written version. In these cases, we compared the original and the re-written versions side by side electronically to determine what changes were made by the student with the re-write and how it affected the grade. The grading effort was extensive and precluded use of more than a single grader, despite the advantages of this latter approach in supporting the study findings. A content grade was additionally recorded for the original submission that would be later used for comparative analysis.

Prior to the first assignment, a questionnaire (pre-test) was given to the students (Table 3) that assessed their attitudes toward science writing and discussion in the classroom. Students were asked whether these pedagogies had an impact on their learning, and whether they have a place in the current course. Likert scale scores ranged from strongly disagree (1) to strongly agree (5). At the end of the semester, a related questionnaire (post test) (Table 3) that was virtually identical with the pre- test was given to the students. Data from the pre/post test analysis provided evidence as to whether students' attitudes changed while using these techniques.

Analysis

Changes in writing grades for grammar/writing style were compared over time using a repeated measures ANOVA with students (N = 16) as a random factor and assignments (time: N = 6) as a fixed factor. The assignment scores used for this test were the revised submissions, if done, or the original submission, if not done. It was felt the revisions were made based on changes in content understanding following the class discussion, not any further understanding or

Figure 1
Schematic Model Described in the Text Depicting the Flow of Assignments, Student Responses and Instructor Assessment

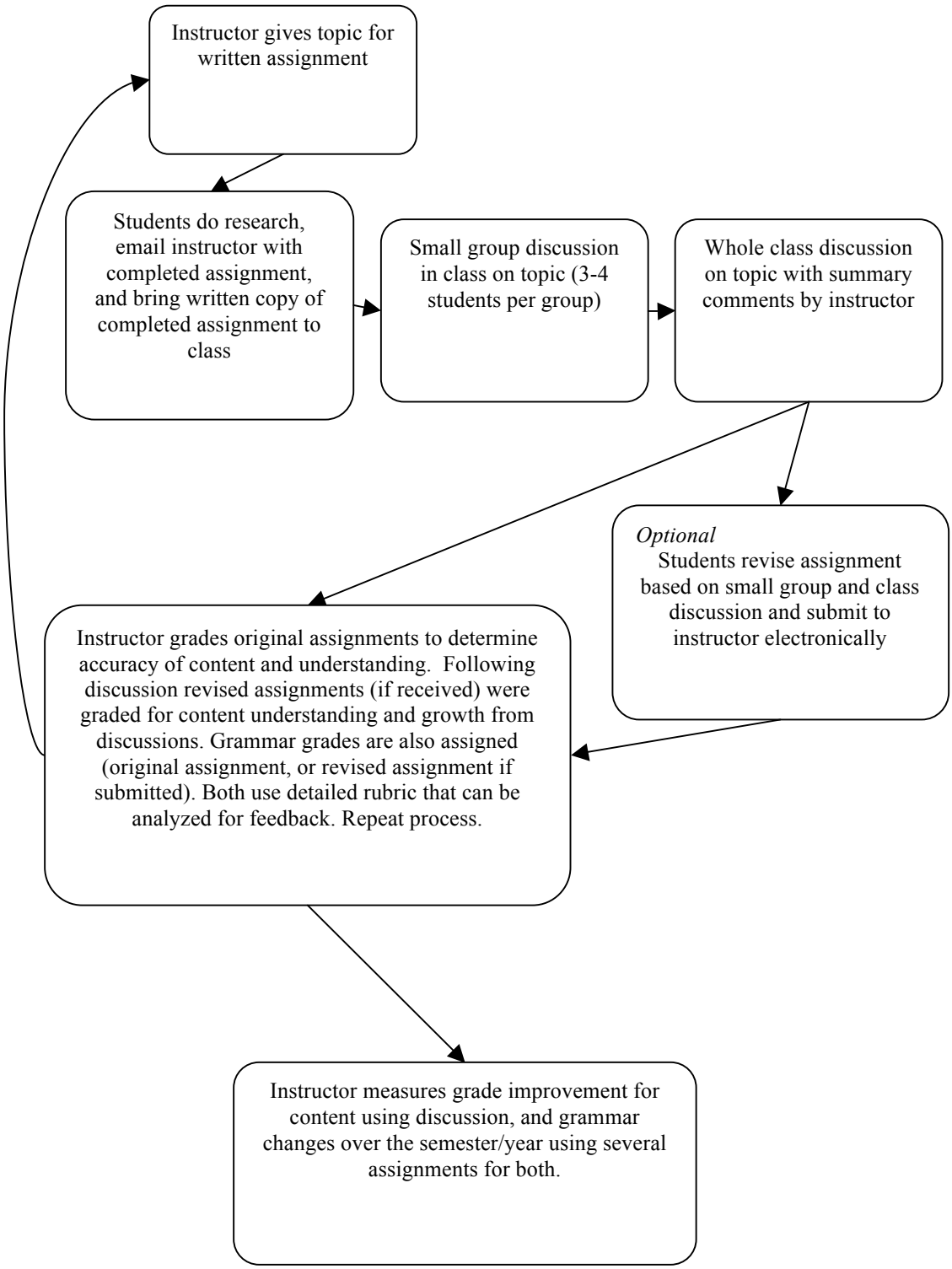

Table 1
Examples of Questions/Assignments Used for the Six Assignments Given During the Study

1. Using a scientific paper review:
   Evaluate the following scientific paper (insert appropriate reference for your discipline here) and provide me with (1) the most important contribution and (2) the most significant limitation.

2. Using several related concepts from the text:
   Describe the relationship between lake mean depth, area, and primary productivity.

3. Using a concept from the text and relating it to current natural resource management application.
   How does the ecological concept of "top down effect" described in your text relate to the trout and salmon stocking programs currently used in Lake Michigan?

Table 2
Rubric Used to Assess Student Written Assignments (N = 6) During the Semester

Grading Rubric:

1. Grammar/writing style: ..... 10 points total

Equal emphasis was placed on each of the eight categories, e.g., 1.25 points/category, with not all points totals equaling a whole number (e.g., 7.5/10)

The writing was grammatically appropriate for scientific communication and standard American English, including:

a. used correct spelling
b. composed complete sentences
c. expressed using clear word choice and absence of awkward and ambiguous words
d. expressed using clear sentence structure and absence of awkward and ambiguous sentences
e. wrote with an absence of punctuation errors
f. drafted a logical paragraph beginning with a well-defined topic sentence followed by sentences that all support the topic sentence
g. included a logical transition to the next paragraph or topic
h. reflects a style of scientific writing appropriate for the discipline

2. Content evaluation ..... 10 points total

Equal emphasis was placed on each of the five categories, e.g., 2 points/category

The student showed a grasp of the content of the assignment as indicated by the following:

a. used the concepts germane to the assignment and defended their choice.
b. synthesized known facts with unknown facts
c. generated a hypothesis regarding the content
d. persuaded the reader to accept a point of view
e. provided information that was technically accurate

clarification of grammar/writing style. Thus, the evaluation used here was based on the assignment grade the students actually received. The intent was to evaluate whether students' writing grades improved as the semester progressed and was unrelated to the class discussion.

The class discussion was evaluated by comparing the content grades of the original assignment submission (pre- discussion) with the re-written assignment (post discussion) grades using a paired t-test. Only assignments that were re-written (N = 59) could be included in this analysis. Both grammar/writing style and discussion tests were used to assess quantitatively the impact of the teaching pedagogy.

Changes in attitudes in the classroom were described using the pre- and post test data. Since attitudes are a type of qualitative assessment not easily quantified, changes were identified using median scores for pre- and post questions and compared using a non-parametric Mann-Whitney test. All tests used $\alpha = 0.05$.

Results

Individual grammar/writing style scores for the six assignments ranged from 5 to 10 (out of a possible 10). Mean (SD) scores ranged from 6.56 (0.72) to 8.43 (1.01) and increased with each assignment from 1st to the 5th assignment, while assignment 6 showed a slight drop to 8.19 (1.01) (Table 4). These values were significantly different from each other and suggested grammar/writing skill improved as the semester progressed. Examples of the original submissions coupled with the editorial suggestions and comments on grammar/writing style are found in Table 5.

Two students submitted only one revision (post discussion) for content understanding, while another only submitted two revisions. All other students

Table 3
Pre- and Post Assignment Questionnaires Used in Class to Evaluate Student Attitudes on Writing and Discussion

Please answer the questions below using the following scale:

1 = Strongly Disagree 2 = Somewhat Disagree 3 = Agree
4 = Somewhat Agree 5 = Strongly Agree 6 = Not Applicable

Pre- Questionnaire	Post Questionnaire
1. Written assignments increase my learning.	1. Written assignments increased my learning.
2. I expect my technical writing skills to improve in this class.	2. My technical writing skills improved in this class.
3. If you have done writing in other biology classes, answer the following -- I would have valued more constructive criticism/comments/feedback on my technical writing skills.	3. I valued the constructive criticism/comments/feedback on my technical writing skills.
4. If you have had small group discussions in other classes, answer the following – *Small group* discussions have helped in my learning and comprehension of the content material.	4. The *small group* discussions have helped in my learning and comprehension of the content material.
5. *Whole class* discussions have helped in my learning and comprehension of the content material.	5. *Whole class* discussions helped in my learning and comprehension of the content material.
6. I learn more technical writing skills from several short writing assignments when compared to one long writing assignment such as a lab report vs. a term paper.	6. I learned more technical writing skills from several short writing assignments when compared to a single long one.
7. Writing assignments in which you are given both written and content feedback are a fair and reasonable expectation for this class.	7. Writing assignments in which you are given both written and content feedback were a fair and reasonable expectation for this class.

submitted at least three revisions out of six possible ones. Individual grades for the biology content material from the assignments ranged from 4 to 10 (out of a possible 10). Mean (*SD*) grade for the pre- discussion assignments was 6.9 (1.25), while the post discussion mean grade increased significantly to 7.80 (1.05) (Table 6). This was a 12.3% increase in content material.

Data on student attitudes (Table 7) seem to agree on the value of writing and discussion from the pre-questionnaire (median Likert scores = 4). The post questionnaire identified changes in student attitudes for both the value of writing and discussion. First, students' attitude regarding specific and detailed feedback they received on their technical writing skill (question 3) seemed to trend upward during the semester (post discussion median score = 5). Students indicated they learned more from several short assignments when compared to a longer one after experiencing this approach (question 6). There also seemed to be a change in their attitude (question 7) about having writing assignments as a fair expectation for the class, although it wasn't significant (p = 0.12). Lastly, students indicated they learned more during the semester from the whole class discussions (question 5).

Discussion

Our data demonstrated that over the course of the six writing assignments with detailed feedback, a single evaluation showed there was an improvement in grammar/writing style (e.g., spelling, punctuation, clear sentence structure). Improvements in writing using a repeated assignment technique have been noted by others (Koprowski, 1997; Moore, 1994; Rice, 1998; Tessier, 2006). We acknowledge a more rigorous method of assessment could have been employed if other graders or a more detailed breakdown of the rubric sub-categories were employed. However, we suggest that even with these limitations and possible bias, improvement in student writing skill was demonstrated. Jerde and Taper (2004) found the only significant factor improving scientific writing performance was prior scientific writing experience. This concept of learning to write by writing was endorsed by Rice (1998), who, as was done in this study, provided detailed instruction and feedback to his science students. The merging of science and writing using "writing-across-the-curriculum" approaches had been touted as having merit, but it is not without problems (Fulwiler, 1984; Griffin, 1985). However, we do agree with Raimes (1980) that writing should not simply be *taught* in all courses, but rather, writing should be *done* in all courses as a pedagogical method to teach content. She further suggests that writing itself improves logic, clarity, and objectivity, all components used to learn subject matter, clearly obligatory in the sciences. Moreover, this concept is not restricted to a single age group or class, but rather, is applicable to all pedagogical environments where students read, write, discuss, and assess information.

Table 4
Grammar/Writing Style Grades (Mean and Standard Deviation) for the Six Assignments Given During the Course of the Semester

Assignment	N	Mean	SD
1	16	6.56	0.78
2	16	7.16	0.57
3	16	7.62	1.30
4	16	7.97	1.36
5	16	8.44	1.01
6	16	8.19	1.01

Note. Changes in grades were significant (repeated measures ANOVA, $df = 5$, $p < 0.001$).

Table 5
Examples of Student Submitted Text, the Correction Advice Given as it Pertained to Grammar/Writing Style, and the Specific Comments Detailing the Advice

Student submitted text	*Instructor revised text*	*Comments*
Other observations noting an increase in phytoplankton production as Secchi disk values have decreased.	Other observations have noted an increase in phytoplankton production as Secchi disk values decreased.	Tense out of sync, deleted "have" as unnecessary,
Light is the main source of energy through out the world. As discussed in chapter nine, the sun is the main source of light. All organisms depend on light/energy to be able to function, grow, and reproduce.	Sunlight is the main source of energy throughout the world and all organisms depend on this light energy, directly or indirectly, to be able to function, grow, and reproduce.	Throughout misspelled, clarified light/energy usage, improved awkward sentence structure
The focus of Cole's chapter 9 in his *Textbook of Limnology* is the role of light in aquatic ecosystems.	The focus of Chapter 9 in Cole (1994) is the role of light in aquatic ecosystems.	Incorrect text citation, not appropriate for the discipline.
Having sufficient nutrients isn't enough for high productivity. The nutrients must be obtainable to those that use them.	Having sufficient nutrients won't always promote high productivity, as the nutrients must be available to autotrophic organisms.	Clarified awkward sentence structure and text meaning
The author tells you the scientific name and the common name so if you wanted to look up the fish you could more easily find them.	In addition, the author provided the scientific and common names for easy reference.	Awkward sentence structure
The rising of pH is done by changing carbon dioxide to O_2. $CO_2+H_2O \rightarrow C_6H_{12}O_6 + O_2$	During the day photosynthesis raises the pH level of water, based on the equation. $CO_2+H_2O \rightarrow C_6H_{12}O_6 + O_2$.	Punctuation (period), equation not included in sentence, awkward sentence structure

Table 6
Content Grades (Mean and Standard Deviation) for the 59 Students That Chose to Revise Their Assignments Following the Class Discussion.

Content	N	Mean	SD
Before discussion	59	6.94	1.25
Following discussion	59	7.80	1.05

Note. Changes in grades were significant (paired *t*-test, $p < 0.001$).

Table 7
Likert Test Question Response Values Showing Changes in Attitudes Regarding Writing and Discussion at the Beginning of the Course (pre) and at the End (post). Questions are shown in Table 3

Question	Pre test			Post test			Mann Whitney
	N	Mean	SD	N	Mean	SD	*p*
1	15	3.73	0.80	16	4.19	0.91	0.11
2	17	3.88	0.99	14	4.07	0.80	0.95
3	16	3.94	0.93	15	4.53	0.83	0.06
4	17	4.18	0.95	16	4.19	1.11	0.81
5	17	4.18	0.88	15	4.87	0.35	< 0.01
6	17	2.76	1.10	14	4.64	0.50	< 0.01
7	17	3.94	0.90	15	4.50	0.89	0.12

The act of researching the assignment and writing a response to the question forced students to read and to try to understand the material prior to class discussions. Although some students' thoughts may not have been scientifically correct, they came to the discussion with a complement of information that could be evaluated, clarified, and refined. This writing to learn pedagogy has been advocated often (Glynn & Muth, 1994; Keys , Hand, Prain, & Collins, 1999; Kirkland, 1997; Moore, 1994; Tessier, 2006).

The assignments assured every student had a written response prior to beginning the discussion, and thus, blank stares and excuses were minimal when asked to participate. Students could assess their answers in the small group environment and could clarify their scientific concepts in the whole class discussion. The researchers acknowledge that other factors could contribute to the content learning of the students, but our inference from changes in scores on our assessment data pre- post strongly suggested content learning did take place. The level of student learning from the discussion was positive and consistent when comparing the pre- vs. post- discussion assignments. The discussion type of learning is typically more productive than lectures (Pestel, 1997), unless well crafted (Cronin-Jones, 2003), and is more in line with the active learning approaches advocated by many (Angelo & Cross, 1993; Bonwell & Eison, 1991; McKeachie, 1999; Sutherland & Bonwell, 1996). Lastly, because students were allowed to re-write their assignments (N = 59) to change content, researchers in this study inferred learning continued after the discussion was completed. Thus, these students were actively engaged in the learning processes before, during, and after the discussion.

The written assignments generated two types of assessment data. First, by comparing the progression of grammar/writing style grades over the semester, learning to write could be measured, demonstrating both direction of change (increase), and the quantity or extent of change. This latter value was not difficult to calculate, but it did require repeated scores. Using the classroom approach of writing a single "term paper" without developmental feedback, this type of assessment would not be possible. The multiple writing assignment concept used here and by others (Miller, 1999; Rice, 1998; Tessier, 2006) promotes a positive learning environment and one that can be quantified. Although some have argued a single written paper can be productive for the student (Bob, 2001; Bowman & Stage, 2002), in our opinion it still requires guidance, review, and revision to be effective.

The second set of assessment data measured the change in biology content scores between the original assignment (pre- discussion) and the revised assignment (post discussion), and gave an indication of the value of the discussion. The discussion facilitated peer assessment and we infer it prompted students to reflect and self-assess their own work. Many (N = 59/96) took the opportunity following the discussion to re-write their assignments – typically to improve their score on a paper that was (at the time) ungraded. We infer students used the peer and self assessment approach (Black et al., 2004) provided them in the classroom discussion to modify their assignments. Although many have argued the benefits of a good discussion (Angelo & Cross, 1993; Ebert-May, Brewer, & Allred, 1997; Gullette, 1992; Weimer, 1987), the ability to quantify the value of discussion escapes most. Our finding identifying an improvement in assignment grades of 12% following discussion is novel, based on our review of the literature, and should be viewed in this context. Although it could be argued this exact percentage improvement may not accurately define the improvement actually due to the discussion, it does give an indication of this technique's value and its potential as a pedagogic tool.

The student response to writing assignments, based on the pre- and post questionnaire that identified their attitudes, did not change regarding the value of writing assignments and the expectation of improvement during the semester (questions 1 and 2). However, the change from "somewhat agree" to "strongly agree" for the remaining questions has several implications. First, the preferential responses of learning more from several short assignments (question 6) and valuing constructive criticism/comments/feedback (question 3) aligns itself with the pedagogy for writing achievement postulated by Moore (1994) and Jerde and Taper (2004). We were concerned the detailed and extensive criticism given may create a negative attitude for students (Ehrlich & Zoltek, 2006). However, this wasn't the case, as the students appeared to take and appreciate the comments with the intent for which they were given. Second, writing assignments with feedback were strongly agreed upon as a fair and reasonable part of the course curriculum. This acknowledgement not only suggested we should structure our course curriculum to include writing assignments, but this inclusion is endorsed by the students. Lastly, the high agreement by students that discussions in both small and whole class formats aided in their learning of the course material is not new pedagogy to instructors. However, it was heartening to see the students' approbation.

Conclusions

This study assessed students' written skills and content learning as influenced by (a) repeated writing assignments with opportunity for revision, and (b) small

and large group in-class discussion using objective measures. From our viewpoint, we crafted a model where students researched a question, formulated a written answer, discussed it with their peers, and revised their answers. Then, we did it with repetition to provide practice and experience. Because we carefully structured the methodology and intent of the assignments, we suggest the assessment data could be used for quantitatively measuring student learning. Furthermore, we infer that the feedback given on the active writing assignments allowed the students to refine their understanding of scientific concepts.

The methodology used in this study lays out a model of teaching and learning that could be followed across disciplines. However, it is ultimately the type and amount of student learning that is paramount in the process. Placing that onus on the student, regardless of grade level, will provide a higher level of achievement.

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