

Writing in STEM: A Synthesis of Two Adaptive Approaches

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Abstract

Providing students with opportunities to improve their written and oral communication abilities can be an effective way to elicit student learning. ABET Criterion 3 speaks directly to the importance of this skillset through Student Outcome g which states “an ability to communicate effectively (3g1 orally, 3g2, written).”¹ There are a number of ways to include this skillset within the assessment component of a typical STEM classroom. With this ABET student learning outcome as a backdrop, this paper will provide a synthesis of two writing-based assessment strategies that will draw upon specific examples utilized in a collection of introductory physics classes. These strategies include free-writing activities and a formal conference research paper activity. The conference paper activity includes an oral presentation component as well; thus, these examples address both components of Criterion 3g. Several studies exist which point to the use of writing-based assessments both in physics as well as in the broader STEM communities. These studies provide a sound research base that suggests that writing-based strategies can not only improve students’ written communication skills but they can simultaneously serve as useful learning tools. The aims of this paper are twofold. First, an overview of how these two writing-based approaches might be embedded within the curriculum as pedagogical tools to help assess just *what* and *how* students are learning will be presented. Second, some suggestions as to how the use of these approaches can be used to provide one measure of student ability to communicate effectively as per Criterion 3g. Because writing activities tend to demand considerable grading time for instructors, many of us tend to shy away from assigning too many of them. This is particularly true for faculty in small departments who don’t have the luxury of having unlimited hours for grading assistants. Hence, a discussion of time-saving grading and assessment methods will also be shared.

Introduction

Student Outcome g of ABET Criterion 3 requires that baccalaureate degree programs must demonstrate that their graduates have an ability to communicate effectively. Communication, broadly speaking, refers to the sharing or exchanging of information, ideas, and concepts. The sharing and exchanging of information typically takes place either through the spoken and/or written word. Coupled with the need to improve students’ ability to communicate effectively is the need to be able to effectively assess whether our students are actually learning what we want them to learn². As Spurlin, Rajala, and Lavelle have suggested, assessment should be a process that is ongoing and one whose aim is to understand and improve student learning.

Assessment of student learning can take on many forms – from traditional tests and quizzes to written laboratory reports, research papers, projects, etc. The focus of this paper will be to provide a discussion about ways to incorporate writing into the curriculum as well as to provide some examples of how writing-based tools can be used to assess student learning. To this end, the use of rubrics can be very worthwhile for both the students and the instructor. As Spurlin has indicated and modeled, the use of carefully crafted rubrics can be a useful way to demonstrate that students have met the criterion whether the communication is through either written or oral form³. In addition, the use of a carefully crafted rubric can help reduce the overall time needed

to grade a particular activity. The use of rubrics can, in fact, be very helpful tools, especially when formative assessment is the goal⁴. Cross and Angelo have been perhaps two of the biggest proponents of formative assessment and their book on classroom assessment remains a seminal work within the educational community⁵. Exams and quizzes are often used as more summative forms of assessment where instructor feedback often comes a little too late for the students to be able to make changes and improvements in their learning.

The ability to effectively communicate is important regardless of the discipline. Within the STEM domains, considerable efforts have been made to design, reshape, modify, and teach courses whose learning objectives speak to ABET criteria⁶. Other efforts have focused on teamwork activities as a means of satisfying the Criterion 3 learning outcomes⁷⁻⁹. Through a survey given to undergraduate alumni of a large Midwest public university, Passow found that respondents indicated that teamwork, communication, data analysis, and problem-solving were among those in the top cluster of competencies that were most important to them¹⁰. Providing students with multiple opportunities to improve their communication skills does more than speak to student outcome 3g. These opportunities also provide students with important skills that will have a direct positive impact on their future careers.

The use of writing-based approaches might seem formidable for an instructor whose subject matter might appear to better lend itself to more traditional problem-based exams and quizzes. However, the use of various writing-based and writing-to-learn-type approaches can be effective assessment vehicles and they can play an important role in increasing student interest and motivation as well as enhancing conceptual understanding¹¹⁻¹⁷. This enhanced interest and motivation, in turn, may serve as a catalyst to improve and enhance student understanding¹⁸. Simultaneously, a writing-based approach when used as a regular assessment tool embedded within the curriculum can also be used as a data point to demonstrate that students have met, and hopefully exceeded the expectation that they can communicate effectively.

In the sections that follow, two practical writing-based strategies will be synthesized. These include the free-writing exercise and a written research paper activity. These writing activities may also be useful for an instructor interested in conducting classroom research. Writing-based activities can be useful for documenting student learning as well as provide an illustration of how they can demonstrate scholarship in teaching¹⁹. This paper, however, will not focus on using writing as a research tool as much as it will focus on how writing can be used to demonstrate the enhancement of students' written and oral communication skills. To this end, this paper will provide a synthesis of two different approaches in which writing can be used to support a course curriculum while concurrently improving the communication skills of the students. Following a synthesis of these writing-based activities, some suggestions will be provided that are aimed at reducing the time needed to grade and assess them. The first writing strategy to be described is known as a free-writing exercise and is synthesized in the next section. The free-writing exercise can be used as a good classroom assessment technique (CAT) and can simultaneously be used to help students improve their written communication skills, as specified in the ABET criteria.

The Free-writing Exercise

The motivation for the free-writing exercises to be discussed was inspired by the *minute paper*, a relatively short and easy to implement classroom assessment technique (CAT) as illustrated by Angelo and Cross²⁰. Because of the strong link between the minute paper as a useful classroom assessment strategy and the free-writing exercises which share a common purpose, a short overview of the minute paper will first be provided.

The minute paper is a quick and easy way to collect written, formative feedback on what students are learning while the learning is actually taking place. One of the benefits of using a minute paper is that they are very short, and take a very small amount of class time to implement. Correspondingly, the time needed to assess student responses is also very short. Depending on what the instructor's particular focus is, a minute paper can be given during the first few or last few minutes of a class session. For example, if an instructor is interested in assessing student understanding of a particular lecture or class session, it would be best to give it during the last few minutes of class time. However, if the goal of the instructor is to assess student understanding of a reading or other homework assignment, the minute paper could be given during the first few minutes of a class period.

The minute paper is typically structured in the form of two short questions such as: "What was the most important thing you learned during our class session today?" and "What important question(s) remain uppermost in your mind as we ended our class session today?" It is recommended that the students' answers remain anonymous in order for them to feel comfortable to share their true understanding (or misunderstanding) of a key concept(s) covered during the class session or based on an assigned reading. If an instructor wants to give the students homework or other credit for these activities they can do so by simply taking attendance. Just passing around an attendance sheet during the class session works well in order to know who completed the minute paper activity. Any form of recording attendance works. Some may prefer to use an electronic form of taking attendance, such as that available with "clicker-type" response systems. For example Turning Technologies has an electronic response system known as Turning Point and it works very well²¹. However, anonymity is not a requirement for either the minute paper or the free-writing exercises.

The commonality between the minute paper and the free-writing exercises is that they both aim to get at student understanding of a particular concept or idea. In addition, they both require a relatively short amount of time to implement and assess. When used in a physics or other STEM class, both activities can help students uncover and confront any misconceptions or incorrect thinking they may have regarding a particular topic(s)²². This is incredibly important as misconceptions can lead to big problems for students later on in a course. It is important to provide students with opportunities to confront and correct any incorrect conceptions formatively while the learning is taking place rather than summatively through a more structured exam or quiz.

The focus of a free-writing exercise can be more specific than a typical minute paper activity. For example, a free-writing exercise might specifically ask the students to explain their understanding about a particular demonstration or other illustration shown in class. Figure 1

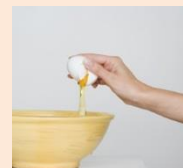
provides an example of a free-writing exercise that was used in an introductory physics course for non-majors. The key concept that was being addressed when this particular activity was given was that of inertia and Newton's first law. The aim of the activity was to assess whether students could connect what they were currently learning about Newton's laws to the broad topic of impulse and momentum. The overall goal was to assess students' prior knowledge of impulse and momentum using the demonstration of the first law as a catalyst. Getting a handle on students' prior knowledge is incredibly helpful in terms of identifying potential misconceptions while the learning is ongoing. As illustrated in the example, students were asked to write a short 2-3 sentence paragraph for each of three questions. Requiring that students keep their free-writing responses very brief also helps to keep the grading and assessment time to a minimum.

For this brief free-writing assignment, I would like you to recall a demonstration you were shown in class recently. **The demonstration involved 3 raw eggs, some empty tissue rolls, a pizza pan, and 3 glasses mostly filled with water.** If you recall, I set the pizza pan on top of the glasses of water. I centered the tissue rolls above each glass of water and placed a raw egg on top of each roll. To demonstrate Newton's 1st Law (Chapter 2) I quickly jerked the pizza pan out from under the tissue rolls. We saw that the eggs fell straight down into the glass of water. Furthermore, when the eggs landed in the water – they didn't break.

What I want you to focus on for this free-writing assignment are the following three questions:

- 1) **What was the significance of the water in terms of keeping the eggs intact?**
- 2) **If the glasses had been empty, would you have expected the eggs to break when they landed? Why or why not?**
- 3) **What key physics concepts do you think might be at work here?**

Please prepare a short paragraph of 2-3 sentences for each question. You do not need more than 3 sentences for each question. Hence, your response should be in the form of 3 short paragraphs. Do not use any outside resource (i.e. your text, the internet, etc.) to answer these questions. Simply use your own words. If you want to include a diagram or other illustration, you are welcome to do so.



The goal of this assignment is to get you thinking ahead a bit. Remember, you will never lose points for an honest attempt at the answer, even if it isn't physically correct. At some point in the near future, we will return to these questions and come up with an answer based on physics. These writing assignments are intended to get you thinking!

Please submit this assignment in the folder you should have that is dedicated to this activity. Be sure you always include all previous assignments each time you submit. I won't put a score on your writing activities until the end of the term, so please don't lose them!

Figure 1. A Sample Free-writing Activity

Within the introductory physics course, students were required to keep track of each of their free-writing assignments in a simple two-pocket paper folder. At the end of the semester, their folders serve as a modified form of a portfolio in that the writing activities could be used to illustrate the evolution and progress of student understanding of key concepts throughout the semester. Typically, the free-writing activities are graded very simply. If a student fully completes each requirement of the activity, they receive full credit. In addition, students receive full credit even if their written explanations of the physics concepts are not correct. Allowing students to get the answer incorrect but still receive full credit has important ramifications. First, and like the anonymity of the minute paper, it allows the students to feel safe and comfortable to write about their true understanding, or misunderstanding as the case may be. Second, it

removes the artificiality so often present in many types of homework assignments where the students will tend to write what they think the instructor wants and not what they truly think and understand. This point alone provides a wealth of useful information about student learning that cannot be as quickly and as easily discovered through other types of homework assignments. Third, continuing these short free-writing activities over the course of the semester and having students collect them in a simple folder also provides evidence of how both the quality of student writing and student understanding can improve over time. Over the course of a given semester, the collection of students' free-writing exercises will often display an expanded knowledge of key physics concepts as their writing becomes more technical. The students' ability to use physics terms and ideas correctly almost always improves as the semester progresses and their ability to express their understanding through writing becomes quite evident. At the same time, the enhanced ability to write more correctly can certainly be linked directly to an overall improvement in the ability to communicate effectively.

The above is just one example of how a free-writing exercise can provide useful information about student learning that can be uncovered very quickly and easily through the active process of writing. How these exercises can be utilized in terms of the overall grading component of a course is as unique as the writing activities are themselves. As indicated, the activities can be assessed in a *receives full credit or does not receive credit format*, or they can be assessed in a more structured way using a simple rubric. Because the goal of these activities is to help students discover where their individual thinking might be off, it is suggested that their assessment reflect that. Keeping the assessment simple also keeps the grading time short.

In terms of grading time, there are some "tricks" that can be used to keep it to a minimum, especially in large classes. For example, if an instructor is teaching multiple sections of the same course, they may choose to give a free-writing exercise, such as that illustrated in Figure 1, to one section of students prior to when the concepts have been covered in class. In this case, the exercise could be given prior to the formal presentation of the concepts of impulse and momentum. Then, the second section of students could be given the same free-writing exercise after the formal presentation of these concepts. In both cases, the exercises are given during the formative stage of student learning so students still have time to correct any incorrect thinking before an exam or quiz has been given. In addition, this cuts down on the grading time substantially because the instructor only has to read and score half as many writing exercises at one time. In a course with multiple sections, it could be quite easily assumed that the composition of students across sections is reasonably similar. Hence, reading the free-writing submissions for just one of the multiple sections would effectively reduce the instructor's time substantially. Reading the free-writing submissions for just one section would work well when formative assessment is the goal. Points could be allotted to the students for simply completing the activities and then any issues the instructor found while reading one section's free-writing activities could be shared and addressed formally during lecture across all sections of the course. Finally, giving these activities before and after a concept has been covered in class also gives the instructor a window into what students knew before *and* what students know after a concept was covered in class. This is extremely useful in terms of assisting an instructor to make necessary changes in the course content and delivery in real time.

Whether students submit their free-writing exercises via paper or electronically, it is important that the instructor provide prompt written feedback²³⁻²⁴. The feedback does not necessarily need to be detailed and lengthy to be effective. A few simple comments from the instructor on a free-writing exercise can tell a student that what they have written is being taken seriously by the instructor. In addition, these comments can let the students know that they are being treated as individuals and that what they have to say about their learning matters. In fact, Hyman indicates that in a preliminary study conducted by a group of college writing instructors, even the briefest personal comment on a student writing assignment can have a direct connection to their paying more attention to and retaining and understanding the other comments and feedback provided by their instructor²⁵.

There are other interpretations of the free-writing exercise as well. Elbow, perhaps the first to write expansively on the notion of a free-writing exercise proposes a different and more literal approach²⁶⁻²⁷. His approach involves frequently (i.e. at least 3 times per week) taking time out to write freely for about ten minutes or so about a particular topic – or about no particular topic at all! Elbow suggests that a free-writing exercise “... is like writing something and putting it in a bottle in the sea. The teacherless class helps your writing by providing maximum feedback. Freewritings help you by providing no feedback at all²⁸. Elbow further suggests that writing, unlike speaking provides for the opportunity to do more editing. Keeping a free-writing diary, he suggests, can be an effective way of improving one’s writing. As such, a free-writing diary could be assigned as an ongoing activity that students could be required to make entries in 2 or 3 times a week. The diary could be collected at various points during the semester and modest feedback provided. At the end of the term the diaries could serve as an illustration of how students’ ability to think out loud through their free-writings has improved their ability to communicate some of the technical content of a particular course.

Kalman has developed another alternative to free-writing through a technique he refers to as *reflective writing*²⁹. Reflective writing involves a hermeneutic approach which begins by having students create a self-dialog about a particular section of textual material. This approach has been widely used in science and engineering classes and has served as a tool to explore relationships between students’ performance as illustrated in their writing products and their individual epistemologies and ways of knowing³⁰. Kalman has students write reflectively about a section of textual material prior to coming to class. The benefit of this student-centered approach is that students must interact with the textual material before they come to class. As the students learn about the material in class they are able to make connections and answer questions that they might have uncovered while they were writing a particular reflective writing activity. In a recent study, Kalman, et al, showed that students’ epistemological beliefs could become more expert-like when combined with appropriate instructional tools including the reflective writing activities³¹.

Ultimately a free-writing type exercise can be used as a relatively short and efficient way to document student understanding over the span of a science or engineering course. By offering students frequent opportunities to write freely an instructor is able to help students correct their incorrect or flawed thinking while the learning is taking place. Simultaneously, the opportunity to write frequently can also facilitate the improvement of students’ ability to communicate effectively through writing. In addition, the writings, when taken collectively may provide some

concrete evidence that students are making progress in terms of improving their ability to write critically about technical material in a science or engineering class.

In the next section, the conference research paper activity will be synthesized. The conference paper activity is a longer writing assignment that serves several purposes beyond those in the free-writing activity. In addition, there is an oral component that is embedded within this activity as students are required to present their research papers at a class conference held at the end of the term. Because this is a longer writing assignment, some suggestions will be provided to help keep the instructor's time to grade and assess it to a minimum.

Overview of Conference Research Paper Activity

The need for students to improve their written communication skills goes far beyond being able to demonstrate that the ABET criteria have been met. Tittle reminds us that STEM degrees are not earned strictly through mathematical and other technically-based courses³². Using data from the National Report Card, she notes that just 52 percent of high school graduates scored at the basic level in writing and just 38 percent at the basic level in reading. This is a troublesome fact given that many of these students will go on to populate our college classrooms. In fact, Trittle notes the rising number of development and remedial courses on reading and writing that continue to rise and have overflowing enrollments on college campuses across the U.S. This fact is quite disturbing.

In an informal study involving 140 community college students enrolled in introductory biology courses and 60 university students enrolled in upper-level biology courses, Ramsey and Baethe reviewed data from class exercises, laboratory reports, numerical and word problems, independent experimental design studies, and final grades. When these data sources were examined, it was noted that students in introductory courses displayed a lack of familiarity with both basic writing and mathematical skills. Students in the upper-level courses appeared to fare a bit better. These students prepared research papers on a variety of topics. They were presented with a rubric pertaining to the paper construction and format. For example, students were required to have a formal thesis statement and the body of the paper needed to address the elements of the assignment. Ramsey and Baethe concluded that while there was some confusion on the part of the students regarding analysis of the topic (e.g. some students had trouble discerning where the analysis stopped and the conclusion began), the papers taken as a whole conformed to the requirements set forth in the rubric and the students scored well.

A research paper assignment such as the one mentioned above is a great start in terms of helping students improve their written communication skills while they simultaneously explore, in a good deal of depth, a topic in a STEM class. The research conference paper to be synthesized here takes the concept of a written research paper to the next level by providing students with an opportunity to experience all aspects of researching, writing, and presenting a formal research paper at an in-class conference. This particular conference paper activity has been implemented for over 15 years in a second-level physics course for non-majors at American University. The course was previously titled Physics for a New Millennium (PNM), but has recently been rebranded as Light, Sound, Action (LSA). Techniques related to the implementation details of the conference research paper activity have been previously reported in the literature and will

simply be summarized in the next subsection³⁵. The focus of the following discussion will be geared towards discussing how the activity can be utilized as a marker to illustrate student ability to communicate effectively.

Implementation Details

Through the semester-long conference research paper activity students experience writing an abstract, multiple paper drafts, a peer review, and the publication of a final camera ready paper in the printed and bound class conference proceedings. In addition, the students present their research papers orally at a class conference held at the end of the term. The paper writing activity takes the place of a standard final exam and consequently is worth 200 points or the equivalent of about 20 percent of the students' overall course grades. During each phase of the paper writing process, students begin to earn points towards their overall conference paper grade.

American University uses the Blackboard web-based platform for all of its classes³⁴. Thus, Blackboard is used as the vehicle for submission of all conference-related activities. On the LSA course Blackboard site, a conference paper folder is set up. Through this folder students can not only submit the required conference-related assignments and activities, but they can also access useful documents which provide them with tips on preparing an effective abstract, some sample abstracts, the conference guidelines along with sample papers from previous classes, and some sample PowerPoint presentations created by former students in previous classes.

The research conference paper activity is introduced to the students at the beginning of the semester. On the first day of class, a formal call for papers is issued. The call for papers is structured similar to a call for papers for a typical professional STEM conference. Potential topic areas are highlighted and students are told that they needed to select a topic for their papers that overlapped in some way with one or more of the topics to be covered in the course (i.e. sound and waves, electricity and magnetism, and light, color, and basic optics). Students are given about 2 weeks to conduct their preliminary research and get their topic "green-lighted" by the instructor. Hence, students have to first pitch their topics either in person or via email to their instructor and demonstrate that they have conducted some initial library research. Once students receive the green light approval of their topics, they proceed to the abstract writing phase.

Students must keep their abstracts to a 200-word maximum. Hence, at this phase, the grading time is quite minimal. Students are not presented with a rubric at this phase of the process, as the aim is to get them to articulate their topics and provide a description of how they will link the topic to the course material in their papers. The abstract is typically worth about 10 points of the 200 points allotted to the conference paper activity. Students earn these 10 points by simply adhering to the call for papers and following through with an abstract that meets the established criteria, word limit, etc. Once the abstracts have been submitted, it takes about 10 minutes per student to read through them and to provide some constructive feedback. As with a professional conference, students are notified via email that their abstracts have been accepted. The instructor's feedback is simply provided as an attached document. While feedback can be given to the students through the Blackboard platform, email is the vehicle of choice for the simple reason that this is the way feedback is most often sent to authors submitting their work to a

professional conference. Hence, the use of email to communicate with students gives them a better sense for how things work in a more professional and outside-of-the-classroom setting.

There are only two real differences between the class conference and a professional conference. The first difference is that all submissions are done via Blackboard. The second is simply that no one gets “rejected” at any phase of the process.

Along with feedback on their abstracts students are also presented with the formal conference paper formatting guidelines. In a subsequent class session, students are also presented with the rubric shown in Figure 2 that is used as a guideline for assessment purposes. The rubric is discussed in some detail in class. The conference papers must be 6 fully-formatted pages in length. The format requires 10-point font in a two column format. This corresponds to about 15 double-spaced pages written in 12-point font. Students have approximately 4 – 5 weeks from the time they receive feedback on their abstracts to get a first draft of their complete papers written and submitted. During this 4 – 5 week period students are typically required to set up a meeting with their instructor to ask about any issues that might have arisen while they were writing, and to clear up any technical formatting issues they might be experiencing. Students normally receive about 5 points towards their overall conference paper score for coming to this meeting well-prepared.

PNM Conference Paper Formative Assessment Criteria*

	4 (Outstanding)	3 (Good)	2 (Satisfactory)	1 (Unsatisfactory)	0 (Mainly non-existent)
Abstract	The abstract demonstrates ambition, thoughtfulness, and appropriate specificity. The abstract provokes readers to reflect on the topic's subtleties and complexities.	The abstract has an ambitious objective statement but does not fully deliver on its promise. Supporting arguments progress with very few lapses in clarity, soundness, or relevance.	The abstract has an objective statement, although it doesn't demonstrate ambition or take on a discernible degree of difficulty. The abstract may be too broad to lead to a focused paper.	The abstract's unsatisfactory objective statement suffers from logical incoherency or facile aims. Numerous lapses in clarity, soundness, or relevance.	The abstract has virtually no discernible objective or direction. Arguments often bear no relation to other sections of the paper; logical fallacies may abound.
Organization	At the global level the paper's organization develops organically from an outstanding abstract. On a local level, the paper flows with appropriate transitions between sections and without unintended interruptions.	At the global level, the paper's organization reveals a logical and effective progression of the objective as given in the abstract. On a local level, transitions between paragraphs and sentences create continuity and coherence.	At the global level, the paper's organizational strategies demonstrate basic cohesion and continuity. On a local level, transitions between paragraphs and sentences usually create continuity and coherence, with some exceptions.	At the global level, the paper's unsatisfactory organization results in a paper that confounds the reader. Locally, paragraphs stumble from one to the next and often lack focus and coherence. Transitions between sections and sub-sections are largely missing.	At the most basic level, the paper's paragraphs lack most defining features of a traditional paragraph: controlling ideas, transitions, unity, and coherence. The same is true of the paper as a whole.
Introduction/ Historical Overview	Provides a thorough and very clear historical context to the paper.	Provides a reasonably thorough and clear historical context to the paper.	Provides a modest and mostly clear historical context to the paper.	Provides a minimal and mostly unclear historical context to the paper.	Provides little or no historical context to the paper.
Physics Synthesis	Provides an excellent overview of key physics concepts at a level appropriate for the target audience.	Provides a strong overview of key physics concepts at a level appropriate for the target audience.	Provides a modest overview of key physics concepts at a level appropriate for the target audience.	Provides weak or minimal overview of key physics concepts at a level appropriate for the target audience.	Provides little or no overview of key physics concepts at a level appropriate for the target audience.
Connection between Key Physics Concepts and Paper Topic	Connections made are clearly outstanding and demonstrate a clear and strong understanding of the topic.	Connections made are strong, and demonstrate a good understanding of the topic.	Connections made demonstrate a basic understanding of the topic.	Connections made demonstrate a weak understanding of the topic.	Connections made are largely absent reflecting little or no understanding of the topic.
Summary	Provides an excellent synthesis of key ideas.	Provides a strong synthesis of key ideas.	Provides a modest synthesis of key ideas.	Provides a weak synthesis of key ideas.	Provides little or no synthesis of key ideas.
Correctness	The writing has virtually no grammatical, mechanical, or formatting errors. Sources are appropriately attributed, documented, and cited. At this level, the presentation reveals the professionalism and attention to detail.	The writing has few grammatical, mechanical, or formatting errors, and they do not distract the reader from the content. Sources are appropriately attributed and cited with very few errors.	The writing has several grammatical, mechanical, or formatting errors, and some errors distract the reader from the content. Sources are documented and cited, though not always strictly in an appropriate format.	The writing has substantial grammatical, mechanical, or formatting errors that distract the reader from the content. Many sources are incorrectly documented and cited.	The paper fails to meet minimum standards of correctness; errors in grammar or mechanics prevent readers from understanding the paper. Sources receive incorrect or no documentation and citation.
Reference Section and Citations	All cited works are done in the correct format with no errors. At least 50% are from non-web sources.	Some cited works are in the correct format. Maintains mostly a good balance between web- and non-web sources.	Few cited works. Done on the correct format with some errors. Over-emphasis on web sources and insufficient major references.	Few cited works. Done in the correct format with many errors.	Absent or the only sources cited are web-based.

*Adapted from AU's College Writing Program Grading Criteria.

Author: _____

Number of fully formatted pages submitted (5-page minimum): _____

Figure 2. Rubric outlining conference paper assessment criteria.

Students receive feedback solely from the instructor on the first drafts of their papers. This is really the only point during the process that takes a good deal of instructor time. Having constructive instructor feedback at the first draft stage is critical for the students. It is at this stage that difficulties with student understanding can be elicited and addressed. In addition, advice on formatting and writing style can also be provided. Many students need assistance in learning how to write a good transition sentence between sections and subsections of their papers, for example. Being able to do so effectively aids them in improving the quality of the paper by providing some necessary clarification for “the reader.” In this context the intended reader is simply another student taking a second-level physics course. Hence, just as with a professional conference the students are writing for an audience of their peers.

Students are encouraged to choose a topic that might blend the key physics topics that will be discussed in the course with their major area of study. To illustrate, three examples from the spring 2015 class will be provide. One student in our School of International Service wrote a paper entitled “Let There Be Light: Bringing More Electricity to Sub-Saharan Africa.” A student in our Audio Technology program wrote a paper entitled “Architectural Acoustics: The Physics of Sound in Constructed Enclosures.” Finally, a student in our International Relations program wrote a paper entitled “Sonar and Stealth: The Geopolitical Implications of Submarine Detection.” These are but three examples illustrating the wide range of paper topics that students typically select to research for the conference paper activity. As can be seen from these illustrations, not only do these topics overlap with the students’ major areas of study, but they also focus on one or more of the key topics in physics that are covered in the LSA course.

Reading and providing feedback after students have submitted their first drafts takes approximately 1 hour per paper. Yes, this is a substantial amount of time, particularly with a large class. Typical class sizes for the LSA class range from about 15 – 20. For a larger class, an instructor might reduce the number of required pages in the students’ papers which would naturally reduce the time spent reading and commenting on them. It is important to note that providing feedback at this point in the semester is much easier to do than during final exams week. At that point in the semester most instructors are laden with grading exams (and papers!). With the conference paper activity, detailed feedback is not needed on the final draft of the paper. Rather, the feedback is provided after the first draft, when the students actually needed it (i.e. while they are still writing their papers). This is really an important difference between the conference paper activity and a standard research paper assignment. Frequently, with a standard research paper assignment the student only gets feedback from the instructor once, and that is after the final paper is written. Thus, the standard research paper often does not provide as much evidence of improved written communication skills as does the conference paper activity.

With the conference paper activity, the students write a first draft for instructor review, a second draft for peer review, and then a final camera ready copy for publication. Hence, there are two critical junctures in which feedback is received prior to the submission of the camera read copy. The two drafts as well as the final camera ready paper, when looked at collectively offer a valuable assessment tool for documenting several things, including the improvement of written communication skills.

When providing feedback on the students' first drafts, it is very time-efficient to simply focus on 1 or 2 pages of the paper. Students can be told that if they have an issue with a missing transition statement at one point in their papers, for example, that they should check their entire papers over for possible additional missing transition statements. Detailed feedback does not have to be provided on every single page of the paper to be effective. In fact, once students receive the instructor's feedback on their abstract that is often enough for them to say to themselves, "Hey, this instructor is really taking this writing-thing seriously and giving me some really good feedback." This realization often translates into more students taking the overall activity more seriously. And again, a reasonably detailed amount of feedback is only given once during the semester, and it comes closer to the halfway point than the end of the semester. It has been this instructor's experience that not having to spend a ridiculous amount of time grading research papers at the end of the term is a real bonus.

Students write and submit a second draft of their conference research papers approximately 4 weeks after receiving the instructor's feedback of their first drafts. At this juncture, students participate in the process of a peer review. Peer review guidelines are established for their structured reviews. Each student is assigned one paper to review. They must adhere to the peer review guidelines and provide constructive feedback on their assigned papers. The feedback received from the instructor on the first drafts of their papers serve as a model for the peer reviews. The peer review activity is worth 50 points or about 5 percent of the students' overall course grades.

By inspection of the feedback students provide on their assigned papers, a considerable amount of light can be shed on their own understanding of the key physics concepts presented in their classmates' papers. Since all papers must include topics that are covered in class, this is a particularly robust way of assessing what students are learning in class in a way that traditional exams and quizzes cannot. Part of the peer review includes having students comment on the format as well as on the writing style used in the paper that has been assigned to them. Having to comment on these items is particularly helpful to the students as the work to complete the final camera ready versions of their own papers.

The final step in the writing process is for students to utilize the feedback they have been provided through both the instructor review as well as the peer review of their individual papers. About 2 weeks prior to the class conference, students are required to submit a final camera ready copy of their papers for publication. The papers are assembled by topic and conference sessions are established. A formal conference proceeding is printed and each student receives a copy for their personal dossier. Students also use their final papers as writing samples when they apply for internships and professional employment. The two conference paper drafts as well as the final camera ready copies serve as useful evidence in documenting both what students have learned in the course as well as their ability to communicate a technical topic in an effective manner.

A class conference is traditionally held on the last day of class. Two days prior to the conference, students are required to present a practice run of their presentation to the instructor. The practice presentations take a full day of instructor time, but it is time well spent! Based on feedback from the instructor the students are able to put the polishing touches on their

presentations before they present them at the class conference. Everything associated with the class conference is done in a professional format. The conference typically lasts for about 5 hours. Each conference consists of approximately 4 technical sessions with papers being arranged by topic. Students must wear professional attire and are given nametags to wear during the conference. Each student completes a review of their classmates' presentations during the conference. The reviews are completed anonymously and then collected and returned to the respective students at the end of the conference. Because the conference activity has been going on at American University for over 15 years, it has become a showcase event for the department. Many faculty and students from other departments and classes attend and support the conference. Many times parents of the presenting students are also in attendance. The presentation component of the conference research paper activity constitutes 75 points or roughly 8 percent of the students' overall course grades. Based on the formal assessment of the students' presentations, formal evidence of the students' ability to communicate a technical topic in physics in an effective manner can be obtained.

Summary

The use of a writing-based approach easily lends itself to multiple forms of assessment, often in a much more authentic way than through traditional tests and quizzes. In fact, the primary purpose of an exam or quiz is to provide a summative marker of a student's progress in comprehending a subject over a given period of time. At best, a final exam grade only provides a single data point regarding student learning. A student's grade on a final exam does not, however, shed much light on the overall process of learning. If one is truly intent on capturing what a student has learned in a given course, other methods of assessment are required. The active process of writing served as a formative vehicle for assessment of student understanding of the course material at various intermediate points along the way. Moreover, these activities can serve as effective data points that formally address ABET Criterion 3g.

The beauty of the free-writing exercises is that they are quite short, very flexible, and reasonably easy to implement. Over the course of a semester, students can assemble their free-writings in a folder or portfolio. Collectively, these writing activities can be used to document both the students' understanding of key concepts as well as show an improvement in their ability to communicate effectively using the technical language of physics.

The conference research paper activity includes both a written and oral component. Hence it can be used to fully address Criterion 3g. The use of a carefully crafted rubric is valuable to the students as they write their papers; and, it simultaneously provides documentation of the students' ability to write and speak effectively on a technical topic. If data beyond what is generated by these assessments is needed, one might consider having a team of faculty review students' camera ready papers using the same (or similar) rubric used to assess them in class. The collective data received from multiple faculty reviewers might serve as documentation of the students' ability to communicate effectively through writing. A similar strategy could be used for the conference paper presentations. Additional faculty might attend the conference to serve as reviewers for the oral presentations. The data obtained from the collective reviews could provide essential documentation of the students' ability to orally communicate a technical topic to an audience of their peers. The two approaches illustrated here may be easily reframed and adapted for use in any course, whether it is a more traditional physics or other STEM-related course.

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