Free-Writing with a TWIST: A Novel Strategy to Enhance Student Learning in Physics

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Abstract

Writing has long been shown to be an effective strategy to enhance and motivate student learning. In an introductory physics or engineering class, it can be difficult to employ a writing-based approach. This difficulty arises in large part because these approaches are often seen as time-consuming when it comes to grading. And, these types of classes are already filled with a great deal of homework assignments that primarily focus on problem solving. These homework assignments often serve as the primary mechanism outside of exams and quizzes to assess student learning. Many of these introductory courses also include a laboratory component. The assessment of the laboratory component typically involves a written laboratory report. Because the introductory classes often have a reasonably large number of students in them, it may be challenging to think about adding a writing component to these introductory classes. The assessment of student writing can certainly be a huge drain on one's time. This paper will focus on a very short writing-based technique used in an introductory physics class at American University during the Fall 2018 semester. This formative assessment took about 5 minutes of class time and the amount of time needed outside of class to score the free-writing assignments was extremely minimal. Following a description of the free-writing activity, two specific examples will be provided. Strategies for quick and easy assessment will also be shared. A unique twist to assessing these assignments involves a Physics Correctness Value (PCV) score. A PCV score provides students with a very simple and quick assessment of their understanding of a particular topic at a particular point in time. These scores can also help students to confront any misconceptions they might have about a given idea or topic in physics. PCV scores can be provided by an instructor, or students can use them to provide feedback to their peers. Examples of how these free-writing activities can be used to boost student understanding and potentially lead to enhanced ability to solve conceptual physics problems will be shared. Time-saving tips for assessing these assignments as well as ideas for adapting this type of writing-based approach in other physics and engineering courses will be shared.

Introduction and Motivation for Study

Good communication skills, especially writing-based skil1s, are essential for students of all disciplines. Employers often indicate that effective communication skills are one of the most important attributes of a potential employee. Possessing solid communication skills is particularly important for students aspiring to technical careers such as those involved in physics and engineering. The application of writing-based approaches in the classroom can help to improve students' communication skills.

The current study was, in part, motivated by changes currently underway to the General Education Program at American University. As a result of these changes to the program, a new set of learning outcomes were created and courses aspiring to be included in the program offerings were tasked with making innovative changes to both the learning opportunities provided to students as well as to the methods used to assess learning. These programmatic

changes provided motivation for the enhancement of a writing-based approach known as free-writing that has been utilized by the author for many years. The free-writing activities have been used to provide students with a unique opportunity to demonstrate their understanding of key concepts in the introductory physics course. The original motivation for the free-writing activities themselves was inspired from the strategies highlighted in the Angelo and Cross handbook on classroom assessment techniques [1]. There Angelo and Cross outline a number of formative classroom assessment strategies (CATs), most of which have a writing component. Along with each CAT presented, Angelo and Cross provide an estimate (low-medium-high) in terms of the time required to prepare the CAT, the time required for students to respond, and the time required for faculty to analyze the data collected. After using the CATs for many years, the author was inspired to create a number of short free-writing activities for use in introductory physics classes. These activities are informal in nature and have the same broad goal as the CATs, namely to formatively assess student learning while the learning is actually taking place. With a focus on the use of writing in the classroom, the following section will provide a brief overview of some of the relevant research in this area.

Literature Overview

Physicists and engineers are often challenged to communicate with others outside their respective disciplines, and often to members of the general public. The importance of being able to communicate through the active process of writing cannot be understated. A number of studies have focused on various strategies to build and enhance the writing skills of students [2 – 16]. Within physics and engineering courses, writing can be utilized through a wide array of applications. For example, technical writing skills are required as students learn to write laboratory and technical reports. Writing can also be used to introduce students to new concepts as well as to reinforce concepts throughout the learning process.

The utilization of a writing-based technique need not always be formal in nature. For example, Bean offers examples of a number of informal and exploratory writing activities [17]. Bean provides "six reasons why he cannot imagine teaching a class without an exploratory writing component" (pp. 121 – 122). These reasons are:

1) My thinking piece assignments continually present students with higher-order critical thinking problems.
2) They change the way students approach course readings.
3) The create higher levels of class preparation and richer course discussions.
4) Thinking pieces are enjoyable to read.
5) They help me to get to know my students better.
6) They help me assess learning problems on the spot.

For physics and engineering educators, items 1 – 3 are desirable outcomes in most learning scenarios. The fact that the thinking pieces are enjoyable to read and allow one to get to know their students better as indicated in items 4 – 5 are certainly positives. Perhaps the most important reason is item 6 which speaks to assessing learning problems "on the spot". Too often, assessment involves discovering problems that students have in their learning after a formal summative assessment has been given. This summative assessment comes too little, too late to

really help students make corrections in their thinking and understanding. By assessing the learning problems right away, students are able to receive critical feedback that can help them improve their learning. Too often students enter the classroom with incorrect preconceptions and misconceptions that unfortunately don't get corrected as a result of more traditional forms of assessment of learning [18 – 25]. Uncovering and dealing with those misplaced preconceptions and misconceptions early on is critically important to helping students wrestle with and eventually replace them with correct conceptions. Hence, informal writing strategies, such as the exploratory writing showcased by Bean, may serve as important learning tools for students. In addition, these types of writing activities may allow educators with opportunities to alter their instruction early on and while the learning is actually taking place. Prompt feedback to students while the learning is happening is essential [26 – 29]. In addition, informal writing activities can serve to help students self-assess their own learning. As Barkley suggests, it is important for students to know their "starting points" [30, p. 127].

Barkley, Cross, and Major also provide a number of different teaching and learning techniques that focus on the use of writing [31]. These authors suggest that "writing as a learning tool can help students deepen their understanding of disciplinary content as well as acquire important thinking skills" (p. 234). The enhancement of critical thinking skills is particularly important within technical disciplines such as physics and engineering. Before outlining the free-writing activities, the following section provides a synopsis of the course setting and student population included in the current study.

Course Setting and Student Population

An introductory, algebra-based, first-level general education physics course at American University provides the setting for the current study. This course covers the traditional mechanics curriculum in most first-level introductory physics courses. The course also includes a lab component and students are required to write a formal lab report each week. The course is similarly structured to the introductory, calculus-based course required of physics and engineering students. The only significant difference between the two courses is the level of mathematics used to explain the concepts covered. The level of rigor between the algebra- and calculus-based courses is comparable. Students in the general education physics course are required to complete challenging homework questions that involve written conceptual explanations as well as numerical, algebra-based problem-solving.

The students enrolled in the introductory course come from all majors on campus. Students typically enroll in the course to satisfy the university's general education requirements for graduation. The Fall 2018 course provides the setting for the current study. A total of 50 students enrolled in the course, 36 men and 14 women.

For the past few years American University has been making changes to its overall General Education Program. Pieces of the program are currently being rolled out, and the Fall 2018 introductory physics course was one of the first to be approved and piloted as a Natural-Scientific Inquiry, Habits of Mind (HOM) course.

The Natural-Scientific Inquiry learning outcomes specify that students will cultivate the following Habits of Mind:

1. Describe, evaluate, and communicate experimental results using appropriate technical, qualitative, and quantitative skills.
2. Analyze and interpret data or theories about natural phenomena, using pertinent scientific terminology, principles, and theories.
3. Synthesize theory, observation, and experimentation to understand the natural world through laboratory, simulation, or field experience.
4. Assess science-related content in popular discourse, daily life, or scholarly research.

Throughout the course, the students are provided with a number of activities in the classroom and laboratory to demonstrate that they have achieved these learning outcomes. Each of the learning outcomes can easily be tied to the use of writing as they describe, analyze, synthesize, and assess experimental results, scientific theories, and science in their daily lives. To help students achieve these learning outcomes and to more effectively engage them with the course material, a set of free-writing activities were re-designed and adapted for use in the Fall 2018 course. An overview of the rationale for the newly revised free-writing activities is provided in the next section. In addition, two specific examples of the free-writing activities used during the semester will be showcased.

Overview of Free-writing Activity

One goal of the free-writing activities was to help students uncover for themselves their respective "starting points" as a particular physics concept was introduced. An additional goal was to provide students with "on the spot" feedback so that they would immediately have a better grasp of both what they already understood as well as lines of thinking that they needed to improve upon. These free-writing activities were done during class, and usually took about 5 minutes to do. Sometimes the activities were used in order to pre-assess what students already knew about a particular concept before it was formally covered in class. In other cases, the activities were used to help enable students to explore more detailed connections between concepts. Once the students completed each free-writing activity, they were collected and then discussed during class. Occasionally the students were tasked with free-writing at the end of class. In this case, the class results were used as a starting point for discussion in the very next class session.

The assessment of these informal free-writing activities is rather unique. One unique aspect comes from the fact that in these writing activities, students never lose any points for getting the physics wrong. Instead, these activities provide students with an opportunity to "fall off the bike, maybe even skin their knees, and then get right back on" without fear of penalty. Each activity included a set of instructions and as long as the student followed them, they received full credit for the activity. While not everyone receives full marks on these activities, they do give students an opportunity to get the answer wrong, and still receive some credit. In addition, these use of these activities has resulted in students feeling more at ease to share their incorrect thinking during class discussions. While it is helpful to know what the correct answer is regarding a particular physics question, it is even more helpful to understand why an incorrect answer is

incorrect. The free-writing activities served to help uncover and understand why incorrect thinking is, indeed, incorrect. This enhanced understanding also helped to strengthen students' ability to self-assess while the learning was taking place.

One twist added to the free-writing activities in Fall 2018 was that in addition to receiving a score on these activities that collectively comprised approximately 8.6% of their overall course grade, the students were also given a second score which was referred to as a Physics Correctness Value or PCV score. The students' PCV scores had no bearing on their course grade and were designed to give students an "on the spot" assessment of where they were at in terms of their understanding of the concept being assessed in the activity. The PCV scores ranged from 1 (low) – 5 (high). A PCV score of 1 meant that a particular response had a low amount of physics correctness. A PCV score of 5 indicated that a response was perfect or nearly perfect in terms of its physics correctness. The idea behind the use of the PCV scores was to provide students an early assessment of their understanding of a particular topic or concept at a particular point in time. If they received a low score, students were not discouraged because they knew the low score would not impact their course grade. Instead, they were often more motivated to learn about the concept so that they would be better prepared for a similar question in their homework assignments, or on an exam or quiz. In addition, when large numbers of students had low PCV scores, this seemed to invoke a more robust discussion in class. Assessing increased motivation levels can be a bit subjective. Based on the increased level of class discussions that have ensued after implementation of the free-writing approach along with the use of the PCV scores, a recent increase in student enthusiasm and motivation has been quite apparent.

The first illustration of a free-writing activity was employed to introduce the students to the concept of inertia and Newton's 1st Law and is illustrated in Figure 1. The students were asked to predict what would happen to some raw eggs during a demonstration that would be shown to them once they completed their responses. The students were given about 5 minutes to complete their responses. Once the responses were collected, the instructor conducted the demonstration and much to the surprise of some students, the eggs fell straight down into the water.

This short writing assignment involves a demonstration we will look at near the beginning of class today. The demonstration involves some simple household items including some glasses mostly filled with water, some raw eggs, some empty toilet tissue rolls, and a pizza pan. **Your task with this activity is to predict what will happen to the eggs when the pizza pan is quickly jerked to the side.**

Using approximately 3 or 4 complete sentences, state your prediction along with as much physics justification as you can. You will be given approximately 5 minutes to write up your response. Don't worry about getting the physics wrong! Remember, in these short free-writing assignments you are never penalized for getting the physics wrong.

Once everyone has made their predictions, I will collect your responses and then we discuss as a class the physics concepts that are at play in this demonstration.

Figure 1. Free-writing example involving Newton's 1st Law.

Once the demonstration had been completed, the instructor, with the help of the students related the results to Newton's 1st Law of motion. A significant discussion followed where students were given the opportunity to share their thinking. As indicated in their responses, many

students got caught up in the cosmetics of the demonstration. In particular, the fact that the pizza pan had a rimmed edge really confused some students. Many were eager to explain during the class discussion that ensued why they thought the rimmed edge on the pizza pan would cause the eggs to land on the table and break rather than to land safely in the cups of water placed directly below. It didn't take too long for the students to realize that the rimmed edge actually helped move the tissue rolls out of the way which cleared the way for the eggs to drop straight down as a result of their inertia. This was a rather memorable demonstration and one that was used as a starting point to introduce additional topics later in the course.

In a second free-writing activity, students were asked to return to the "egg demonstration" they had written about earlier. This time, however, the free-writing activity as illustrated in Figure 2, was used to introduce them to the concepts of momentum and impulse.

For this brief free-writing assignment, I would like you to recall a demonstration you were shown in class earlier this semester. **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 is the following question:

What was the significance of the water in terms of keeping the eggs from breaking?

Please prepare a short paragraph including at least 2-3 complete sentences to respond to this question. 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!

Figure 2. Free-writing example involving momentum and impulse.

This second free-writing activity was given to students shortly after they had been presented with the concept of momentum and before students were provided with a formal presentation of the concept of impulse. One aim of the second free-writing activity was to get students to see that there was more physics involved with the earlier egg demonstration than perhaps they initially had thought about. Thus, it was intended to help students make their own connections between key concepts. And of course, the activity was intended to help motivate and engage students to want to learn more about momentum and impulse.

Shortly after the second free-writing activity was given, the students were shown another demonstration that related to momentum and impulse. That demonstration involved throwing a raw egg into a sheet that was held up by a pair of students. The student throwing the egg was asked to first toss it into the sheet very slowly and gently, and the students were not surprised that the egg didn't break. When the student was then asked to toss the egg much faster and harder, the students were very surprised that the egg still did not break. This demonstration led into a more detailed class discussion on momentum and impulse. Students were encouraged to make linkages between this demonstration and the responses they'd written to the second free-writing activity. The reason the eggs didn't break in either scenario had to do with the fact that for a given impulse, the water and the sheet both served to increase the time it took for the eggs

to stop, thus decreasing the possibly damaging impact force. These topics were eventually more formally assessed on a subsequent hour exam.

In addition to responding to the activity showcased in Figure 2, the students were also asked to rate their confidence levels in terms of the responses they had written to the question posed. Students were asked to rate their confidence levels on a scale from 1 – 5. A confidence level rating of 1 reflected that the students had very little confidence in their response. A 5 rating indicated that they were very confident in their response. Providing a confidence level rating was the second new twist to the free-writing activities.

The next section will begin with an analysis showcasing the second free-writing activity which focused on the concepts of momentum and impulse. Aggregate data will be presented pertaining to students' PCV scores as well to their confidence level ratings. To help uncover whether or not the students' understanding of the concepts of momentum and impulse improved following the implementation of the activity, aggregate scores on two specific questions related to the concepts of momentum and impulse posed on a subsequent hour exam are presented.

Data and Results

There were 35 students in class on the day the second free-writing activity was given. The results of their PCV scores are provided in Table 1. Table 2 shows the students' self-reported confidence level ratings on the same activity. It should be noted that Table 2 reflects confidence level ratings for 34 students as one student did not complete that portion of the activity.

Table 1. Aggregate Data for PCV Scores on Second Free-writing Activity

PCV Score	Number of Students	Percentage (%)
5	2	5.7
4	1	2.8
3	2	5.7
2	15	42.9
1	15	42.9

Table 2. Aggregate Data for Confidence Level Ratings on Second Free-writing Activity

Confidence Level Rating	Number of Students	Percentage (%)
5	5	14.7
4	11	32.4
3	12	35.3
2	6	17.6
1	0	0

Upon comparison of the data presented in Tables 1 and 2, there appears to be a bit of a disconnect between students' present understanding of the concepts involved in the free-writing activing and their level of confidence in their individual responses. Interestingly, no students gave themselves a confidence rating of 1, yet nearly 43% had PCV scores of 1. This low score provided an indication that there was very little correct about the physics they attempted to use in their response. In fact, about 85% of the class received a PCV score of 1 or 2, indicating that at best, they had a very minimal understanding of the physics needed to correctly respond to the

question. Hence, there seemed to be a significant divide between the students relatively high confidence level ratings and their actual level of correct understanding as indicated by their low PCV scores. It was expected that the low PCV scores would signal to the students that their understanding was not correct as evidenced by their free-writing responses. Simultaneously, it was anticipated that the low PCV scores would serve to motivate the students to probe a little deeper into understanding the correct answer to the question posed. The broad aim of the activity was that student learning would be enhanced if they took the time to understand why their responses were incorrect or mostly incorrect.

To uncover whether student performance and understanding improved following the second free-writing activity, two questions related to the concepts of momentum and impulse were presented to the students on an hour exam that was given about two weeks later. The hour exam was worth 100 points (11.5 % of the overall grade). The two questions posed to the students were collectively worth about 9% of their exam score and were presented to them as follows:

Question 1. The force on a dropped apple when hitting the ground depends upon

A) whether or not the apple bounces.
B) the speed of the apple just before it hits.
C) the time of contact with the ground.
D) … all of the above.
E) … none of the above.

Question 2. As was demonstrated in class, if you throw a raw egg onto the floor, it will break. However, if you throw it with the same speed into a soft, sagging sheet, it won't break. Carefully explain the significance of the sagging sheet in terms of keeping the egg from breaking. Be sure to make clear the key physics concept(s) involved in your response.

Question 1 was worth 3 points. The correct response is option C. For this multiple choice question, the students either got the question correct or they got it incorrect. There was no partial credit or explanation required of the students on any of the multiple choice questions on the exam. Question 2 was worth 6 points. Tables 3 and 4 provided the aggregate data and associated scores for Questions 1 and 2 respectively.

Table 3. Data and Results for Question 1

Response	Number of Students	Percentage (%)
Correct	34	68
Incorrect	16	32

Table 4. Data and Results for Question 2

Number of Points Received	Number of Students	Percentage (%)
6	10	20
5	13	26
4	7	14
3	16	32
2	4	8
1	0	0

The results shown in Tables 3 and 4 do indicate a significant improvement in the students' understanding of concepts related to impulse and momentum. While not all students got both questions correct, a substantial number of students did show an improvement in understanding based on the aggregate data shown. Important to note is that following the implementation of the second free-writing activity, approximately 85% of the students received a PCV score of 1 or 2. For exam question 1, 68% of the students made the correct choice. For exam question 2, 46% of the students received scores of 5/6 (83.3% correct) or 6/6 (100% correct). While it would be unrealistic to attribute the improvement in students' scores solely to the use of the free-writing activity, these results are certainly encouraging.

Summary and Tips for Adaptation of a Free-writing Approach

One outcome of the free-writing activities was that classroom discussion was enhanced and much more robust. As indicated after the first free-writing activity was given and the corresponding demonstration shown to students, the level of class enthusiasm and discussion was increased. The free-writing activity seemed to allow students an increased level of security and comfort as they freely shared their incorrect lines of thinking with the rest of the class. Because the class was relatively large in size, this is particularly important to point out. Often times, the larger a class is, the less students feel comfortable to share their thoughts with the rest of the class. The free-writing activities seemed to quell student apprehension and facilitated a free exchange of thoughts and ideas (whether correct or not) with the rest of the class.

As noted earlier, the use of the PCV score and confidence level ratings provided a new twist to the free-writing activities. The level of improvement students showed as demonstrated by their scores on the two related questions posed to the on the hour exam provides some promise that they are fairly effective in boosting student understanding. This fact has inspired the author to continue and enhance their use in the Spring 2019 introductory physics class.

In terms of tips for other educators desiring to adapt a free-writing approach into their own physics or engineering classroom, it is suggested to start with just a couple of activities. Trying to do too much too quickly could backfire depending on the size of the class. If the class size is large, implementing one or two activities during the semester is recommended. That would allow an instructor to get a better feel for how long these activities will take them to implement. If the activities are short, such as the two highlighted in this paper, implementation should be very manageable. Short activities take very little class time (about 5 minutes) and very little time outside of class to score. For the 50 students in the Fall 2018 class, assessment and scoring of each activity took less than one hour of time outside of class. Because these free-writing activities are used to foster class discussion, and because the correct responses are highlighted at that time, a minimal amount of written feedback to the students is necessary. Most important is to provide students with prompt feedback. Prompt feedback also helps to ensure that the students take each activity seriously.

An additional tip for educators considering the adaptation of a similar writing-based approach, is to have students do a concise peer review of each other's papers during class and to give their classmates a PCV score. The peer PCV score could then be compared to the PCV score provided by the instructor. This strategy was employed once during the Fall 2018 class, and results were a bit mixed. In the Fall 2018 class the students were asked to exchange papers with a neighbor and to provide a PCV score prior to the class discussion. Asking students to provide a PCV score on a classmate's paper prior to the class discussion seemed to be out of order in

terms of providing students all the tools they needed to provide their scores. In the Spring 2019 class the author plans to collect the free-writing activities and then discuss the correct results during class. Following this discussion, the activities will be randomly distributed to the students and each student will be asked to provide a PCV score for one of their classmate's responses. By conducting the discussion prior to asking them to provide a peer PCV score, it is hoped that the scores will be more accurate and meaningful for the recipient.

The results presented for the second free-writing example showcased in this paper are promising. For the next iteration of these activities in the Spring 2019 class, the author plans to use the students' exam responses as a springboard to a new free-writing activity. This new activity would involve having students analyze their own responses to the exam questions. This analysis will involve having them write about what part of their exam response was correct and what part was incorrect. For the incorrect portion, students will be asked to briefly explain why their thinking was incorrect. A comparison of responses to similar questions on a final exam could then be used to assess whether their understanding of the concepts of momentum and impulse improved between the time the hour exam and the final exam was given.

In summary, one aim of these short free-writing activities was to provide students with immediate and often on-the-spot feedback in order to facilitate their ability to correct flaws in their own thinking. The results presented provide some evidence that the activities are serving to aid students in making the necessary corrections to their thinking. An important part of the learning process is to have opportunities to make and correct mistakes. Too often, summative types of assessment such as quizzes and exams come too late for students to be able to correct any flaws in their understanding. Short, informal free-writing activities can serve as one type of formative assessment that allows students to have this important opportunity to improve and enhance their learning.

References

[1] Angel, T. A. and Cross, K. P. (1993). *Classroom assessment techniques: A handbook for college teachers (2nd ed.).* Jossey-Bass Publishers: San Francisco, CA.

[2] Connolly, P. and Vilardi, T. (1989). *Writing to learn mathematics and science.* New York: Teachers College Press.

[3] Enns, C., Cho, M., and Karimidorabati, S. (2014). Using writing as a learning tool in engineering courses. *Teaching Innovation Projects*, *4*(2). Retrieved from https://ojs.lib.uwo.ca/index.php/tips/article/view/3678.

[4] Elliott, L. A., Jaxon, K. and Salter, I. (2017). *Composing science: A facilitator's guide to writing in the science classroom*. Teachers College Press: Columbia University, New York, NY.

[5] Elbow, P. (1998). *Writing without teachers (2nd ed.).* Oxford University Press: New York, NY.

[6] Elbow, P. (1998). *Writing with power: techniques for mastering the writing process (2nd ed.).* Oxford University Press: New York, NY.

[7] Elbow, P. (2012). *Vernacular eloquence: What speech can bring to writing*. Oxford University Press: New York, NY.

[8] Hein, T. L. (1999, May). Using writing to confront student misconceptions in physics. *European Journal of Physics*, Vol. 20, 137 – 141.

[9] Wheeler, E., and McDonald, R. L. (2000). Writing in engineering courses. *Journal of Engineering Education*, 89(4), 481 - 495.

[10] Larkin-Hein, T. (2001, January - August). Writing as a teaching and learning tool in SMET education. *Journal of SMET Education: Innovations and Research*, Vol. 2, Issue 2/3, 25 - 35.

[11] Kalman, C. S. (2007). *Successful science and engineering teaching in colleges and universities.* Bolton, MA: Anker Publishing Company, Inc.
[12] Larkin, T. L. (2013, January). The evolution of assessment within an introductory physics course. *International Journal of Engineering Pedagogy (iJEP)*, Vol. 3, Special Issue 1, 39 - 48. Kassel University Press GmbH, Kassel, Germany. eISSN: 2192-4880. http://dx.doi.org/10.3991/ijep. v3iS1.2393.
[13] McKeachie, W. J. (1994). *Teaching tips: Strategies, research and theory for college and university teachers (9th ed.)*. D. C. Heath and Company: Lexington, MA.
[14] Dunn, R. and Griggs, S. A. (2000). *Practical approaches to using learning styles in higher education.* Bergin & Garvey: Westport: CT.
[15] McNeal, A. P. and D'Avanzo, C. (1997). *Student-active science: Models of innovation in college science teaching*. Saunders College Publishing: Fort Worth, TX.
[16] Boyd, G. and Hassett, M. F. (2000). Developing critical writing skills in engineering and technology students. *Journal of Engineering Education*, 89(4), 409 – 412.
[17] Bean, J. C. (2011). *Engaging ideas: The professor's guide to integrating writing, critical thinking, and active learning in the classroom* (2nd ed.). Jossey-Bass: San Francisco, CA.
[18] Arons, A. B. (1990). *A guide to introductory physics teaching*. New York: John Wiley & Sons.
[19] Halloun, I. A. and Hestenes, D. (1985). The initial knowledge state of college students. *American Journal of Physics*, 53(11), 1043 – 1055.
[20] McCloskey, M., Caramazza, A., and Green, B. (1980). Curvilinear motion in the absence of external forces: Naïve beliefs about the motion of objects. *Science*, 210, 1139 – 1141.
[21] McDermott, L. C. (1984). Research on conceptual understanding in mechanics. *Physics Today*, 37, 24 – 32.
[22] McDermott, L. C. (1991). A view from physics. In M. Gardner, J. Greeno, F. Reif, A. H. Schoenfeld, A. diSessa, and E. Stage (Eds.), *Toward a scientific practice of science education* (pp. 3 – 30). Hillsdale, NJ: Lawrence Erlbaum Associates.
[23] Hammer, D. (1996). More than misconceptions: Multiple perspectives on student knowledge and reasoning, and an appropriate role for educational research. *American Journal of Physics*, 64, 1316 – 1325.
[24] Reif, F. (1995). Millikan lecture 1994: Understanding and teaching important scientific thought processes. *American Journal of Physics*, 63(1), 17 – 32.
[25] Van Heuvelen, A. (1991). Learning to think like a physicist: A review of research-based instructional strategies. *American Journal of Physics*, 59(10), 898 – 907.
[26] Wiggins, G. P. (1993). *Assessing student performance*. San Francisco: Jossey-Bass Publishers.
[27] Larkin, T. L. (2012). Closing the loop: What do they do with our feedback? Portuguese Society for Engineering Education (SPEE) Newsletter (Sociedade Portuguesa Para A Educacao Em Engenharia), 5, p. 19.
[28] Chen, J. C., Whittinghill, D. C., and Kadlowec, J. A. (2010). Classes that click: Fast, rich feedback to enhance student learning and satisfaction. *Journal of Engineering Education*, 99(2), 159 – 168.
[29] Calvo, R. A. and Ellis, R. A. (2010). Students' conceptions of tutor and automated feedback in professional writing. Journal of Engineering Education, 99(4), 427 – 438.
[30] Barley, E. F. (2010). Student engagement techniques: A handbook for college faculty. Jossey-Bass: San Francisco, CA.
[31] Barkley, E. F., Cross, K. P., and Major, C. H. (2005). *Collaborative learning techniques: A handbook for college faculty.* Jossey-Bass: San Francisco, CA.