AC 2008-725: LEARNING THROUGH ERROR RECOGNITION USING THE THREE STRIKES METHOD

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Learning Through Error Recognition Using the Three Strikes Method

Abstract

From the collapse of the Tacoma Narrows Bridge, to the crash of the Mars Climate Orbiter, simple mistakes can have catastrophic effects. From the ashes of such mistakes, come important lessons learned and the hope of never repeating them. Discovery of mistakes can be a valuable learning tool that can leave a lasting impression on those who make the discovery.

Throughout the engineering education process, students are asked to work problem after problem to assess their abilities. Many times students, without thought, view the grading of such problems as being purely right or wrong. If their answer is correct they move on to the next problem, and if their answer is wrong they still move on to the next problem. Students need to be aware of errors and where these errors take place. Recognition and acknowledgment of these errors can be a powerful reinforcement tool to the specific engineering principal.

One such error recognition method is called "Three Strikes". As discussed in this paper, the Three Strikes method encourages students to analyze and recognize mistakes. The instructors using this method will purposely, and sometimes un-purposely, inject mistakes into lecture and laboratory problems. The student is encouraged and rewarded for identifying mistakes. Once a mistake is found, the problem is further analyzed to see how such an error would have affected the final results.

Introduction

Learning from history has always been a valuable teaching tool. Scanning the cable television channels you come across multiple shows discussing historical and practical aspects of science and engineering. One such series, discusses engineering disasters throughout the ages. Each story thrashes out mistakes that were made in the implementation or design of an engineering project and sometimes shows how a simple mistake or change could have avoided catastrophes.

These engineering mistakes have been numerous. Some mistakes have been huge oversights missing complete concepts like the Tacoma Narrows Bridge. The Tacoma Narrows Bridge, known as Galloping Gertie, collapsed on November 7, 1940. The collapse brought engineers world-wide to the realization that aerodynamic phenomena in suspension bridges were not adequately understood in the profession nor had they been addressed in this design. This resulted in wind tunnel testing of all existing and future bridges across the country. New mathematical theories of vibration, aerodynamics, wave phenomena, and harmonics as they apply to bridge design arose from these studies. [1]

Other engineering disasters were caused by simple misunderstandings as in the case of the Mars Climate Orbiter. The Mars Climate Orbiter, 191.1 million dollars, smashed onto the Mars surface on September 3, 1999. The 'root cause' of the loss of the spacecraft was the failed translation of English units into metric units in a segment of ground-based, navigation-related mission software. [2]

Examples, like these, are often used in engineering classes to teach principle concepts. Students need to be aware of historical mistakes but also need to search and recognize errors in their own design. Recognition and acknowledgment of these errors can serve as a reinforcement tool for given engineering principles.

Problem solving is the ability to combine previously learned principles, procedures, declarative knowledge, and cognitive strategies in a unique way within a domain of content to solve previously un-encountered problems. From a problem-based approach, a professional preparation of curriculum is organized around fundamental or critical problems encountered in professional practice. [3][4]

The problem-based approach has been a long standing practice in the instruction of engineering. A fundamental part of the problem solving process is the ability to identify errors within the sequence of the perceived solution. Discovery of mistakes can be a valuable learning tool that can leave a lasting impression. A primary benefit that can be expected from well-conceived and problem-based learning is high student interest and motivation. [5] As discussed in this paper, one such method, Three Strikes, encourages students to analyze and recognize mistakes and errors. Finding these mistakes can lead to further analysis on how errors affect results.

The Three Strikes Method

The Three Strikes Method (TSM) is an implementation of an error detection and problem solving assessment method. It has been implemented in several courses taught by the author in the Electrical and Computer Engineering Technology Department (ECET) at Indiana University Purdue University Fort Wayne (IPFW). The TSM, used mainly in an ECET course, can also be easily implemented in other curriculums.

The original concept of TSM was discovered with the help of a student. One day in class, a student noticed a mistake in a substantially long problem being placed on the whiteboard by the author. We continued working the problem with the error and then reworked the problem after correcting the mistake. Once both the correct and faulty answers were found, I pointed out how such an error on my part could have devastating results.

The student who had found the error possessed a large smile upon his face. The smile, partially from correcting his instructor, was intensified when I rewarded him one “brownie” point. The

students already knew that a brownie point, like a high-five, was my way of saying thank you. The student, smile still beaming, responded, "I'd rather you dismiss class early today", to which I replied, "Two more strikes like that, and we will go home early". With those words, the Three Strikes Method was born.

The Three Strikes Method encourages students to analyze and recognize mistakes. The instructor using this method will purposely and sometimes un-purposely inject a mistake into lecture, homework or laboratory problems. The student is encouraged and rewarded for identifying mistakes. The students are encouraged to find three mistakes, or three strikes, during lecture. If the students find three mistakes, the class will be dismissed.

The TSM has been developed, altered over a three-year period. Initially the process in itself was a bit of a joke, but over time the students really became actively involved from semester to semester trying to find mistakes. This has led the author to establishing guidelines for the Three Strikes method. The guidelines, not rules, are at the discretion of the instructor.

TSM Guidelines

1. *Errors can be intentionally or accidentally placed in lecture, homework or lab.*
   This allows for the special development of problems that can be incorporated into course work that reinforces the principles being taught. Unintentional mistakes, further reinforces that the instructor be meticulous in preparation and presentation. Sloppiness, on the instructor's part, can lead to a very happy class of students going home early.
2. *Errors must be written and of a technical nature.*
   Since the TSM was developed in an engineering technology program the students' concentration should be on the technical content. Limiting errors to written technical information helps the student focus on the technology. Mistakes of a verbal nature are not counted since this type of scenario can lead to a he-said, she-said situation.
3. *Errors must be identified by the students, prior to the instructor correcting them or identifying them.*
   An error is not an error unless it can be identified. If a given mistake is not caught, it can have devastating affects. The student is not awarded for something they cannot find. Furthermore, if the instructor finds an unintentional mistake prior to the students, it can be corrected without penalty to the instructor.
4. *Identified errors must be properly corrected by the student.*
   The identification of the error is only half of the solution. The student must identify the location of the error and what the proper correction should be. This causes the student to further analyze the problem. Team work is encouraged in such a situation. Many times a single student will identify an error but the proper correction comes from other students.
5. *Errors in spelling, grammar and punctuation are not considered errors.*
   Proper punctuation, grammar and spelling are stressed as important and required in homework and other professional writings of the student. During the problem solving

stage and initial design, focus is placed more on technical mechanics of a problem. Correctly identifying spelling, grammar and punctuation is encouraged but does not count as a strike.

6. *Each error must be analyzed on how it affects the outcome.*
   Each error, as encountered, must be analyzed by the student and/or instructor to see how it affects the overall outcome. Some errors, especially those found toward the end of class, can be assigned as homework. The student can then summarize the comparisons between the good and bad results of a problem. This is truly where error based applied learning can be enriching

   Estimation is another technique that can be used hand-in-hand with TSM to reinforce a given principal. Estimation is an approximate calculation of quantity, degree or worth. Many times students do not check their answers bearing in mind if the result actually makes sense. Using the TSM, the instructor can show how variants in the problem can change the results and how simple estimation can be used to help predict valid results.

7. *What happens when you find a third strike?*
   The goal for the student is to find a third strike and go home early. One of the goals of the instructor is to instill in the student the principles set forth in the course. When a third strike is found, before leaving, the student must ensure that step 6 has been completed. The error must be properly analyzed and any administrative tasks still needing completion must also be finished before dismissal. These administrative tasks would include assigning homework, handing back homework and answering all questions. Other awards could also be given in lieu of early dismissal.

TSM Examples

Each lecture has a handful of different locations in which errors in problem solving can be inserted. The area in which this author teaches is Electrical and Computer Engineering Technology (ECET). Through the years, different examples of using TSM have been developed for the ECET curriculum. Below, one such example is discussed.

The Karnaugh mapping (K-map) method is used for minimizing a Boolean expression, usually aided by a rectangular map of the value of the expression for all possible input values. Maximal rectangular groups, that cover the inputs where the expression is true gives a minimum implementation. The student is taught this technique in order to produce the simplest implementation of a digital electronic design.

Proper use of the technique, teaches the student to create groupings or loops of the outputs that are adjacent, in order to create terms in the final equation. Loops of a given K-Map must follow some simple rules. You always group outputs into the largest possible group. You only group outputs adjacent to one another, no diagonals. Grouping sizes can be only 2^n (1, 2, 4, 8…etc.). The top and bottom of the K-map, as well as, the sides attach to one another. Following these rules gives the simplest possible Boolean equation for a given function.

Figure 1, demonstrates a common error that takes place when performing groupings in a K-Map. In this figure, two separate loops are created. This particular looping of a K-Map produces the expression $X = \overline{A}\,\overline{B} + \overline{A}B$. This expression is clearly in violation of the rule, grouping into the largest possible group.

	$\overline{C}$	C
$\overline{A}\,\overline{B}$	1	1
$\overline{A}B$	1	1
AB	0	0
$A\overline{B}$	0	0

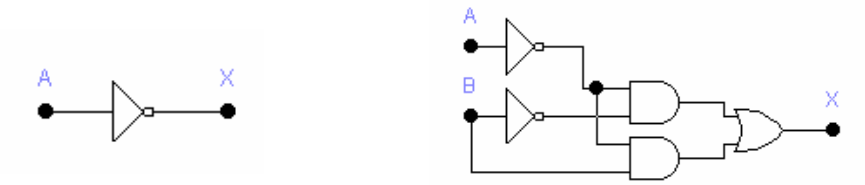
Figure 1

Figure 2, demonstrates the proper method of grouping the same K-Map. In this case, a single grouping of 4 is created with the adjacent outputs. This will no longer violate any of the K-mapping rules. The expression produced is $X = \overline{A}$.

	$\overline{C}$	C
$\overline{A}\,\overline{B}$	1	1
$\overline{A}B$	1	1
AB	0	0
$A\overline{B}$	0	0

Figure 2

Once the error, in Figure 1, is noticed both resulting expressions can be derived from their respective K-maps. The power of this small mistake is amplified by the circuits the expressions create (figure 3).



(a) $X = \overline{A}$ (b) $X = \overline{A}\,\overline{B} + \overline{A}B$

Figure 3

Even though both circuits are equivalent, the correct design (Figure 3a) has a much smaller implementation than the design with the error (Figure 3b). This impact is very visual. The student should also keep in mind other factors affected by this simple mistake. Maintenance of the device is more difficult, the physical size of the device is larger, the device generates more heat and the cost of producing and powering the device will be higher.

Injecting simple errors into problems can leave a lasting impression on the learner. This impression can be further amplified by the fact that the student identifies and is rewarded for this action.

Assessing TSM

The key to any effective teaching technique is in its assessment. Is the technique valuable and effective for the material being taught? Since TSM was implemented in stages over a long period of time, solidly ground finding are hard to obtain. The assessment and effectiveness of TSM has been from the observation of the author.

TSM in itself is not necessarily designed for every course. TSM implementation is better suited for course work involving problem solving. Since the author of this paper teaches an array of courses at his institution, he has offered courses where TSM is not used. One observation made by the instructor is that class participation is substantially higher when TSM is used. An estimation of 30% higher class participation has been suggested.

This 30% estimation can be a bit misleading and several factors need to be considered. In general, the author has found that classes that have problem solving, due to the complexity of the solution, get more questions asked than that of traditional lecture courses. Furthermore, TSM has been implemented in mostly freshman courses. The author has noticed, through the years, that freshman seem more boisterous than upper classmen. However, being boisterous does not necessarily lead to good questions being asked or creating constructive conversation about the subject matter. The author, in his estimation, has kept these factors in mind.

Another non-obvious factor that has been noticed is that of class morale. Receiving a grade on an assignment or exam is a very personal affair. When students receive grades, many times, they will quickly tuck away the paper before others can see it. They either celebrate the thrill of victory or the agony of defeat in the silence of their own minds. With the TSM method, this is a true team effort. One student finds the error and all help to correct it. Team accomplishment is achieved when that third strike is found. The author has been witness to actual cheers and high-fives of victory by the students.

Some instructors have expressed a concern about dismissing class early and loosing valuable instruction time. Yes, some instruction time will be lost during the semester. This time is typically very small and happens sporadically throughout the semester. The instructor controls

the number of errors and can determine how often the reward can be achieved. Normally, the third strike can be arranged toward the end of the class so limited instruction time is lost. The reward must be achieved periodically in order to encourage the students to continue searching and analyzing. Alternative rewards, such as raffles or goodies, can always be a substitute if early dismissal is not practical.

Conclusions

As discussed throughout this paper, the Three Strikes Method encourages students to analyze and recognize mistakes. The instructors purposely, and sometimes accidentally, inject mistakes into lecture and laboratory problems. This leads to student participation by encouraging them, through awards, to identify mistakes. Once a mistake is found, the problem is analyzed to see how such an error would affect final results.

Throughout the engineering education process, students are asked to work problem after problem to assess their abilities. TSM is an additional tool that can be used to help in the assessment process. This method has been successfully integrated in a variety of courses, leading to increased student participation and error recognition. Simple error correction can be a powerful reinforcement tool to almost any engineering principal.

Bibliography

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