

**Expanding Frontiers -  
Challenges and Opportunities in Maritime Education and Training**

**Developing A Culture of Attentiveness**

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**Abstract:** In 1998 Mr. William O'Neil, the then Secretary-General of the International Maritime Organization (IMO), stated that human error is the biggest threat to people working at sea. [1] Since then, the technology involved in operating ships has improved tremendously, but human error is still at the root of most safety issues that arise. The Manila amendments to the STCW Code set out certain safety concerns that contribute to human errors. Specifically it identifies lack of training, new technology and fatigue as areas that contribute human errors. [2] However this paper focuses on another error– that of making inadvertent errors.

It is the intention of the authors to use our teaching experience and tools that we have developed to adjust our teaching pedagogy. The goal of this effort is to encourage students to reorganize their approach to problem solving with the goal of reducing the commonly observed inadvertent error. Pedagogical content knowledge includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them ... If those preconceptions are misconceptions, which they often are, teachers need knowledge of the strategies most likely to be fruitful in reorganizing the understanding of the learners. [4]

The purpose of this project then, is to develop a teaching strategy that will promote a reduction in the observance of these careless errors.

## **1. The Inadvertent Error**

Numerous sources cite human error as the largest singular cause of accidents at sea. There is an abundance of literature demonstrating how human error resulted in major accidents and how what appear to be small or innocuous human errors can be critical contributing factors to a sequence of events resulting in catastrophe.

There are also errors that occur that have much less dramatic outcomes but are still very significant, such as the case of human error causing a cruise ship to tilt abruptly during calm seas resulting in furniture and debris flying about and passenger injury. [3] Even minor human errors resulting in incorrect fueling or incorrect parts being stocked or incorrect measurements being taken can result in financial, operational and/or safety concerns at sea.

Many of the aforementioned human errors can be attributed to either mental or manual errors in calculations. It is the authors' belief that inadvertent errors in calculations are promoted by evaluation methods employed in administering many of our post-secondary courses. The authors believe that making inadvertent errors can become habitualized and result in complacency and inaccuracy in both the solving of problems involving mathematics as well as the development of solutions to other types of problems.

When teaching trivial mathematics such as that learned in elementary school, much of the instruction and practice of the math skills is rote. The simple and correct calculation method is demonstrated through repetitive practice and continuous feedback as to whether or not the answers given to problems are correct, students learn to give the correct answer when posed with that type of question.

As one advances through the education system, problems become increasingly complicated and challenging. The case where a student is asked a simple question requiring a one-line answer becomes increasingly rare, and more common is the case where students are asked to solve problems in which evaluations require successive calculations and even pages of workings to arrive at a single final answer.

As educators of applied math problems, the frequency with which we observe students actually submitting the correct answer to a complex question on either a test or assignment has become minimal. This has been encouraged and promoted through the granting of part marks for solutions based on the correct method being used. Indeed, part marks have been granted for many if not all of the evaluation devices used in many of the courses delivered. Students have come to expect part marks and have become accustomed to earning a passing grade in an assignment or a course even when most of the final answers to the evaluation devices are wrong.

The authors believe that the attitude that this reinforces through the evaluation method promotes complacency towards calculations, and ultimately towards decision making. The authors have adopted a new method of administering applied math courses which re-introduces the importance of the correct answer and which we expect will demonstrate improved calculation accuracy and precision.

## 2. The Inadvertent errors in calculations

The inadvertent error came to the authors attention over the last few years when students were given relatively simple and routine questions as part of a final exam. The performance on these questions was strikingly poor. The students were forewarned that they would be seeing a number of simple questions on the final exam which would only require the selection of the appropriate equation and the use of the right number or numbers in the equation. However there was a catch - *the questions would be evaluated only on whether the answer was correct or incorrect (i.e. no part marks)*. Even with the simple nature of the questions and advanced warning of what to expect, students did not perform well. Table 1 summarizes the questions and response rate for the questions for a class of 24 students.

Question	No. of Correct Respondents [ /24]	% Correct
You have a force of 7.8 N acting on each square mm of a metal block. What is the stress in that metal block.	14	58
You need to weld a bracket to the middle of a bulkhead. The bracket is 15 cm wide and 7 mm thick and will carry a load of 75,000 N. If the weld material is ASTM A36, what length of weld would you need?	13	54
You have a riveted connection made of 3 rivets (AISI3102, 6mm in diameter). What is the allowable stress on the connection using the condition of shear?	14	58
A steel S380x64 beam is used as a cantilever 5 m long with a uniform load of 11,000 N/m. What is the deflection at the free end of the beam.	12	50

Table 1, Results from simple questions given to 24 marine engineering students

Contrary to what might be expected, it was observed that students actually did worse on the less difficult questions than on the more difficult ones. This was demonstrated by the fact that the average mark on the exam from which the above questions were taken was over 60% but the average score on the easy questions was 55%.

The above questions may or may not seem easy to the reader depending on their background, but for the class in which they were administered, they would be considered as trivial. At this level, the student would have already passed a course in mechanics as well as an introductory course dealing with stress. In addition, students would have completed two relevant physics courses, 2 previous math courses and a course on the properties of materials. Students at this level should have enough background knowledge to solve these questions. Subsequently, it is hypothesized that inadvertent errors come into play.

### 3. Current Treatment of the Inadvertent Error

While the inadvertent error has always existed, it is becoming more prevalent as more of the work done either on ships or to support ships is based on precise mathematical relationships where a small calculation error can have a potentially large impact.

With highly technical courses it is very common to differentiate between an error in principle and a careless calculation error with the former being penalized much more heavily than the latter. This is natural since as instructors we are interested in teaching and assessing what is relevant to our course. Consequently it can be argued that a small slip along the way should count as a minimal reduction in marks if any at all. However, taking the larger view it can also be argued that a wrong answer is still a wrong answer. It does not matter if the error is a small one or a major one if it causes the ship to run out of fuel or to capsizes.

Thus instructors are placed in a quandary. Do we mark what is relevant to our course or do we grant marks based on the consequences of the impact of the answers (both good and bad) in the workplace?

While this dichotomy has always existed, the impact of it is becoming more pronounced in modern shipping for a number of reasons. To begin with, if we compare a marine officer's job as it is now to what it was 50 years ago, there is so much more technical knowledge involved that educational institutes are now forced to teach new areas of theory, and indeed more theory than at any previous time. While the deck side has undergone significant changes in regards to technology, the engineering officer's job is almost unrecognizable from what it was 50 years ago.

Another reason for the increasing importance of precision is the technology being employed on ships today. With an increased reliance on digital and automated systems, a instruction based on a small error can multiply into a catastrophe easily.

### 4. How to Emphasize Accuracy while still Rewarding Knowledge of Principles

There are a number of barriers to emphasizing a correct answer as opposed to a correct principle. One was mentioned above (i.e. courses are set up to teach a particular skill set and test the knowledge gained in that course). However a second is that a focus on the end result leads to an increase in students plagiarizing from each other or, if available, other sources.

To address this issue the authors are taking advantage of a tool called Maple TA. In 2010 the authors received an Instructional Development (ID) grant from the Office of the Vice-President (Academic) of Memorial University of Newfoundland (MUN) to purchase a software package called MapleT.A. This software is a web-based application facilitating the creation of algorithmically generated and knowledge-based questions and administering them to students in the form of homework, quizzes and tests. This means that while students will receive similar assignments with similar questions, the numbers will be different, and of course the answers will be different.

Questions can be formed into assignments using a variety of delivery options. In addition the amount of feedback students receive can be authored to be very complete and detailed and issued to the students working on the assignments in a variety of ways through these same options. The courses in which the authors intend to perform this study lend themselves to long and rather complex applied mathematics type questions for both assignments and tests. Through the multi-year development of the question database, the authors have developed a set of questions and assignments that encourage students to be careful and meticulous in their calculations and require that they give the correct answers at the end of the assignment to receive full marks.

The problem shown in Figure 1 is a challenging, yet typical problem taught in a course called Strength of Materials. The student would plot a graph by calculating the parameters labelled 'V' and 'M' at several prescribed locations along the diagrammed beam. The student is required to provide these final calculated values in the answer fields of the software application to a precision of  $\pm 1.0\%$  in order to have that answer marked as correct. The comprehensive feedback solution for this question is as shown in the appendix.



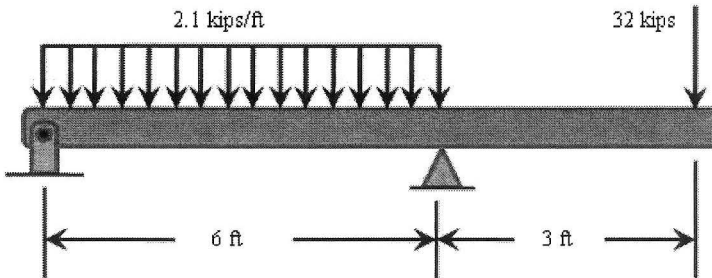
Grade Refresh Close

Description: Q5 Distributed and Overhang W15

Jump To: [Question](#) | [Information Fields](#)

**Question:**

Problem 5 {Problem Value = 15}



For the beam and loading shown, complete the table below necessary to draw the shear force and bending moment diagrams (each answer in this question is worth  $\frac{1}{20}$  of the question value, NOTE that the required units for each column are given in square brackets unless you are required to put in the units yourself.), and draw the shear force and bending moment diagrams. All calculations are performed with 4 significant figures.

The reaction force at support A is:  kips

The reaction force at support C is:  kips

x	V [kips]	M [kip ft]
0	<input type="text"/>	<input type="text"/>
2	<input type="text"/>	<input type="text"/>
4	<input type="text"/>	<input type="text"/>
6	<input type="text"/>	<input type="text"/>
6	<input type="text"/>	<input type="text"/>
9	<input type="text"/>	<input type="text"/>

Rows for cut 1 are Green and rows for cut 2 are Blue.

{Please note that you may retry this assignment up to 5 times. Click grade after you have put in answers for all of the assignment questions, and then you will be able to view the worked solution following each attempt. The grade of your best attempt is the one that will be recorded for this assignment}

Figure 1, A typical Maple TA Question

The policy employed in administering an assignment to a group of students is that the students each receive the same set of algorithmically generated questions. The question shown above is one of a set of three questions that the students would receive for this particular week long assignment. There are five attempts permitted on this assignment. An attempt is defined as a student submitting the complete set of questions for grading. The assignment may be printed for offline work, and the randomly generated elements of the question will remain unchanged until the student submits an assignment attempt. When a student submits an assignment attempt, they are shown the complete set of comprehensive solutions in the form of feedback. They may save and review these solutions at any time, but when they obtain a new version of the assignment after submitting an attempt and reviewing feedback, the randomly generated elements in the question have all changed.

The correct solution method is demonstrated in class and reinforced through the feedback, but student consideration of the problem and calculation accuracy and precision are reinforced through the requirement of the correct set of answers for full marks in the assignment.

This software has been in use at the MI for two years and some clear observations can be made at this point. Firstly, students are spending more time on their individual assignments. There may have been plagiarism on assignments in the past, but now the instructors who use this tool promote student collaboration in the form of discussion of methods to solve the assignment problems. This is a good thing since much of shipboard work requires working in teams. However, where each student receives the same question set but with a randomly generated set of numbers for their personalized assignment, it can be trusted that each student performs their own workings for their own assignments.

It is felt that this software can be used to increase the care a student takes in their work with the goal of making the quick accurate performance of relatively simple tasks a habit. Qualitatively this was observed in the class results from last year's students. After using Maple TA for their assignments, student performance appeared to have improved on the same type of questions as shown in Table 1 with an average score now being 61%. It should be noted that this is a subjective result and not the results of a prepared trial and lacked baseline data for comparison. However it indicated that there would be benefit in performing a formal study.

## 5. Methodology for Testing the Improvement in Inadvertent Errors.

The intent of this study is to gauge the effect of the instructional method and evaluation of the accuracy and precision of manually performed calculations. To this end, for each group of students we consider we will first have to determine baseline data to evaluate how precise and accurate they are in performing calculations before we begin our course. Then we will teach the course and use tools and evaluation methods which will require them to be accurate and precise in order for the students to obtain marks for the evaluation tools being used. Finally we will administer a similar test to that which was given at the start of the course in an attempt to assess the impact of the course delivery method on calculation accuracy and precision.

How assignments are administered can be controlled (using MapleT.A.) by the instructor, but the authors have chosen to have up to five attempts at each assignment granted to the student. When a student submits an assignment the student will receive immediate feedback as to their score on the assignment and will have access to the complete correct solution to the assignment as it should have been submitted for full marks. If the student is not satisfied with their mark, or if they simply want more practice, they may make another attempt at the assignment.

The primary theme of the assignments delivered in the course is to reinforce solution methods for applied math type problems that were taught and demonstrated in class. The underlying theme of the assignment philosophy is to train students to apply the correct methods, but just as importantly to reinforce with the students that precision and accuracy in calculations must be consistently maintained in order to receive the full grade for that course element.

During the applied math course being taught, the students will be coached and instructed in the use of MapleT.A. to receive and submit their assignments. Student will be fully informed on the policies programmed into MapleT.A. and all assignment questions will have a clear statement regarding the precision required in their calculations as well as a margin of error that is programmed into each question to define what is acceptable as a correct answer by the software.

In point form, the assignment policy is:

1. Questions in assignments will include a statement of the required number of significant figures to be carried in order to obtain the correct answer.
2. A small margin of error, typically on the order of  $\pm 0.5\%$  will be acceptable from the answer calculated perfectly using the stated number of significant figures.
3. Each assignment submitted shall be graded independently of the assignment submissions before it. To obtain a perfect score of 100%, all questions in the assignment must be submitted with correct answers within the previously stated criteria in the same submission.
4. The solution to each assignment question shall be made available following the submission of each complete set of assignment questions.
5. All assignments shall be algorithmically generated and the numbers in each question shall be randomly generated. All assignment questions will have at least 10 000 possible permutations.
6. The highest grade achieved on any of the submissions of an assignment will be the mark awarded to the student for that assignment.
7. Part marks for assignments will not be granted based on workings but some questions may have multiple parts and marks may be awarded for each part independently.

Questions for mid-term tests and the final exam for the course shall be developed with the same requirements of accuracy and precision, but part marks will be granted based on workings.

## 6. Evaluating the Improvement:

At the start of each course where student performance will be measured for this study, the authors intend to benchmark the students. A test will be administered consisting of a series of short math and applied math questions based on material that was taught in previous courses and in high school. An example of such a question might be to calculate the area of a complex geometric shape made up from simple shapes and appropriately dimensioned. The skills are trivial but logic must be employed and both precision and accuracy have to be employed in order to get the correct answer. Accuracy must be good in the sense that the correct numbers must be used in the calculations in order to obtain the correct final answer. Precision will also be evaluated by offering similar questions multiple times, such as the case where the complex shape is used in several questions but the dimensions vary each time.

Each student will receive a test consisting of 30 such questions and the test will be administered through MapleT.A.. A time limit of 50 minutes will be applied to the test which will force the students do their best to work quickly yet with accuracy and precision.

The same test (with different randomly generated numbers) will be administered to the students at the end of the course with the intention of measuring the students calculation accuracy and precision before and after the course.

## 7. Conclusions:

The shipping industry, more so than most, is unforgiving when it comes to making errors. This includes small inadvertent errors that appear inconsequential as well as major misunderstandings. While these errors tend to fall into the category of “human errors”, it is felt that their cause is not fully captured by the traditional factors involving human errors such as fatigue or insufficient training.

Instead it is felt that developing a habit in students to calculate quickly, but more importantly accurately, will help to reduce these errors. This will be done by emphasizing the importance of having all stages of a solution correct.

The authors have outlined a methodology that will be applied to evaluate the effectiveness of emphasizing the importance of accuracy in student work. It is expected that accuracy will improve and provide students with a valuable skill that they will use throughout their careers.

## References

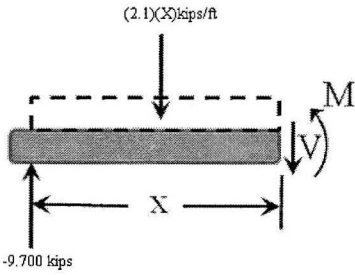
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## Developing A Culture of Attentiveness

Cut 1:



$$+\uparrow \sum F_Y = 0$$

$$\curvearrowleft \sum M_A = 0$$

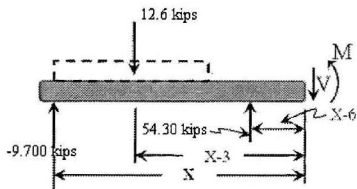
$$-9.700 - 2.1 \cdot X - V = 0$$

$$(-9.700)(X) + (2.1 \cdot X) \left( \frac{X}{2} \right) + M = 0$$

$$V = -2.1 \cdot X + (-9.700) \text{ kips}$$

$$M = -1.05 \cdot X^2 + (9.7) \cdot X \text{ kip} \cdot \text{ft}$$

Cut 2:



$$+\uparrow \sum F_Y = 0$$

$$\curvearrowleft \sum M_A = 0$$

$$-V + (-9.700) - 12.6 + 54.30 = 0$$

$$M - (-9.700)(x) + (12.6)(x - 3) - (54.30)(x - 6) = 0$$

$$V = 32 \text{ kips}$$

$$M = 32.00 \cdot x - 288.0$$

