Improving Student Problem Solving Skills in the Identification and Correction of Errors

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Abstract

Engineers and engineering technologists are faced with a number of different types of problems in industry. In addition to finding solutions to traditional problems, one other type of problem encountered is critically reviewing a set of calculations or a design to identify and correct errors. Checking design calculations is typically performed in industry prior to issuing a final design.[1] The purpose is to provide a quality product and limit professional liability associated with professional engineering practice. In addition to checking design calculations, the study of engineering failures often involves the search for what caused the failure.[3] In many cases these failures can be traced to calculation errors, incorrect design assumptions, or inappropriate application of theory.[3] Unfortunately, traditional problem solving in technical courses usually does not directly emphasize the skills necessary to solve these types of problems. Most problem solving in technical courses is focused on taking a problem statement and developing a solution to provide the required answer. Assessing whether the answer provided with an existing solution is correct requires skill in problem interpretation, solution diagnosis, and attention to detail.[8] To improve student skills at reviewing calculations to identify and correct errors, a "Syntax Error Analysis" concept has been developed. The concept involves giving the students a problem statement along with an erroneous solution. Students are required to analyze the problem and determine where errors occur in the analysis and make corrections. Several trials using this type of problem have been conducted and student feedback obtained. The results have been used to further develop and improve this type of learning experience. Assessment of whether solving problems of this type improves student problem solving skills necessary for identifying and correcting errors is also discussed.

I. Introduction

Problem solving techniques used in engineering and engineering technology courses typically present the student with a problem for which a solution must be found by applying concepts learned in class. This approach involves reading the problem, extracting "Given" and "Required" information, and developing a solution. This is the common way of learning new material. In many cases in industry, a problem solution has been developed, but the result is incorrect. The problem then becomes one of reviewing the erroneous solution and identifying and correcting the errors. In some cases, the presence of errors is obvious due to an absurd result. In other cases, the error is not apparent until the solution is studied and the errors identified.

Syntax error analysis problems are designed to provide students experience solving these types of problems. Students are asked to review a problem and identify any errors and indicate why they are errors. In addition, students can be requested to correct the problem.

Syntax error analysis problems are intended to improve student skills in identifying and correcting errors. These problems can also emphasize important concepts often causing difficulty for students. Studying erroneous solutions can help students improve their attention to detail when solving traditional problems. These types of problems prepare students for the task of critically reviewing and correcting calculations prepared by themselves as well as others.

II. Concept Development

Although most consulting and industrial firms strive to minimize errors in technical calculations, errors still occur. Quality assurance and loss prevention procedures are utilized to identify and correct these errors prior to project completion to provide safe and reliable engineering designs.[1] Consulting civil engineering firms require checking of engineering design calculations prior to a final design being delivered to the client. Checking usually includes consideration of whether appropriate theories and equations were used. Numerical operations involved in the calculations are checked as well. Additional checking may involve reviewing that the results of the calculations are properly transferred to the design drawings and the specifications for construction.

Another type of industry problem encountered is evaluating a design that has failed. This requires a forensic study into the cause of the failure. In this case, the failure will be evaluated to identify the cause. This will often include a thorough review of the engineering calculations used to develop the design. These reviews may uncover that improper theories were used, that conditions assumed in the design were different than the actual conditions, or unit conversions used incorrectly or neglected. Depending on the failure, the results of these errors can be catastrophic and often result in legal action. An example is the failure of NASA's $125 million Mars Climate Orbiter. A review board found that neglected unit conversions caused the failure.[2]

Case histories show that calculation errors often result in engineering failures.[3] Studying case histories of engineering failures helps students avoid the same mistakes.[4] Since engineering and engineering technology graduates will encounter error identification and correction in industry, the skills necessary should be included in the engineering curriculum.

Engineering textbooks typically present examples illustrating the correct procedure to solve a problem. Authors should also consider discussing how not to solve a problem.[5] From experience, they could present some of the common mistakes students make when solving certain types of problems.

During quizzes and tests, students often can not identify their own mistakes as they proceed through a problem. These errors often result from students rushing through a problem solution without taking adequate time to read the problem, identify what is required, and select the appropriate procedure for solution.[6] Asking if the answer obtained makes sense should be emphasized in problem solving.[7]

In addition to understanding the technical material, the skills needed to identify and correct errors within a problem include interpretation of the problem statement, problem diagnosis, and attention to detail.[8]

Interpretation involves reading the problem statement, determining what information is given either directly or indirectly, and identifying what is required.[8] Diagnosis involves the selection of the correct procedure for solving the problem, while eliminating incorrect procedures.[8] Attention to detail requires careful evaluation of the mathematical operations involved in the solution.[8] To help develop these skills, incorrectly solved problems were given to students for their review and correction.

III. Concept Implementation

The "Syntax Error Analysis" concept of problem solving has been introduced at the University of Pittsburgh at Johnstown in several courses on a trial basis. In-class and take-home quizzes containing erroneous solutions were given, to evaluate student ability to identify a variety of errors in a single problem. A questionnaire obtained student opinion and input on this type of exercise.

Implementation occurred in sophomore level engineering mechanics courses in statics and dynamics. The students were majoring in civil, electrical or mechanical engineering technology. Most were at the sophomore level but several were juniors and seniors. Three trials have been conducted, as listed in Table 1.

Table 1. Syntax Error Quiz Trials

	Trial 1	Trial 2	Trial 3
Semester	Spring 2000	Fall 2000	Fall 2000
Course	Dynamics	Statics	Dynamics
Number of Students	45	52	4
Quiz Format	In-Class	In-Class	Take-Home
Number of Errors	5	5	4

The quizzes consisted of one problem containing the number of errors indicated in Table 1. The errors were commonly observed on previous student exams and quizzes.

For the in-class quizzes, students were aware this type of quiz would be given. A syntax error analysis problem was presented in class prior to the take-home quiz. On each quiz, a blank table was provided for students to identify and explain the errors. In addition to completing the error identification table, students were also asked to make corrections and provide a revised answer to the problem. Students were given 20 minutes to complete the in-class quiz. The number of students in each trial is noted in Table 1.

Students were able to identify most errors relatively easily, indicating they understood those concepts fairly well. Other errors were not as easily identified indicating additional time needs to be spent on these topics. Correcting the errors in the time allowed was more difficult on the in-class quizzes.

IV. Student Feedback

A questionnaire obtained student opinions on the quiz and the syntax error analysis procedure. The questionnaire was discussed in class and completed by the students prior to the graded quizzes being returned. The survey consisted of seven questions evaluating the quiz on a scale of one to ten. Two additional questions asked the students to write down their opinions on what they saw as favorable and unfavorable about this type of quiz and the learning experience. The final question asked the students to elaborate on how they thought this type of quiz could be improved. After completing the survey, the graded quizzes were returned to the students and the solution and errors were discussed.

Table 2 summarizes the questions addressed by the students on the questionnaire and the average response for questions one through seven.

The results of Questions 1 and 2 indicate students perceived the syntax error quiz to be as difficult or slightly more difficult than the traditional quiz. In Question 3, students indicated they found it relatively difficult to identify errors in the problem.

The response to Question 4 suggests students perceived justifying "why" something was an error required a level of "reasoning" or "thinking" higher than normally required for solving problems. The response to Question 5 suggests students found it somewhat difficult to provide corrections to the solution after they had identified the errors.

Question 6 indicates students were mixed in their preference of having more quizzes using the syntax error approach. Question 7 suggests students taking in-class quizzes felt this type of quiz did not contribute significantly to their understanding the material previously taught. Students taking a take-home quiz, however, felt this type of quiz contributed significantly to their understanding of the material.

Question 8 asked the students what they found favorable about the quiz from a learning perspective. Some students felt this type of quiz had no favorable aspects relative to their learning. Most students indicated there was something positive about the quiz and the learning experience. They felt the procedure required more thought than a conventional quiz where procedures are often just regurgitated from memory without fully understanding the reason for using a particular procedure. Others noted the quiz really tested their knowledge and whether or not they understood the problem. Several students described it as a stimulating or challenging experience. A number of students said it helped them realize the type of mistakes they could make and gave them practice for checking their own work. A few noted this type of quiz gave them practice for checking problems in industry.

Table 2. Student Feedback Questionnaire and Average Student Response

No.	Question	Average Student Response		
		Trial 1	Trial 2	Trial 3
	Your perceived level of difficulty of the			

1	traditional quizzes in technical courses is: 1 (easy) to 10 (difficult)	7.23	7.21	7.5
2	Your perceived level of difficulty of this “Syntax Error” quiz is: 1 (easy) to 10 (difficult)	8.25	7.07	7.5
3	How easy/difficult was it for you to identify the errors in the erroneous solution? 1 (easy) to 10 (difficult)	7.50	7.10	6.75
4	What was the level of “reasoning” or “thinking” you had to do to justify in your mind “why” something was an error? 1 (low) to 10 (high)	7.18	7.11	7.75
5	After mentally analyzing the problem solution and finding the errors, how easy or difficult was it for you to then provide the corrections necessary for the proper solution? 1 (easy) to 10 (difficult)	6.77	5.64	5.75
6	Your preferences to having another quiz using the “Syntax Error Analysis” method. 1 (no way) to 10 (definitely)	4.77	6.28	6.00
7	Strictly from a learning experience, how much did this type of quiz help you understand the subject material previously taught? 1 (no learning) to 10 (significant learning)	4.91	5.52	7.75
8	What did you find favorable (in terms of the learning experience) from this type of quiz? Please elaborate.	-	-	-
9	What did you find unfavorable (in terms of the learning experience) from this type of quiz? Please elaborate.	-	-	-
10	What can be done to improve this type of quiz so it enhances the student learning experience? Please elaborate.	-	-	-

Question 9 asked the students to identify what they felt was unfavorable about the quiz relative to their learning. A number of students commented on similar unfavorable aspects of the quiz. For the in-class quiz, students felt there were too many errors, having to find the errors and then make corrections was too much work, and many said more time should have been allowed for what they were asked to do.

A number of students also did not like errors being carried through the entire problem. In the first trial, some errors carried through the problem. This confused the students. They were unsure whether or not to consider the error a new error each time it appeared in the problem.
The erroneous solution was organized differently than some students organized their work. They had a hard time following the solution and started questioning everything in the problem. One said it required doing twice the work of a conventional problem. More space should have been

provided for the corrections and describing the reasons for the errors. Some also admitted they did not understand the material and could not solve the problem themselves, much less find the mistakes in someone else's solution. One student said they would rather make their own mistakes. To some, the quiz tested them on how well they could find errors, rather than their knowledge of the material. Others did not like having to do this type of problem as a timed quiz. They knew the material, but because of the format, they would be getting a low grade.

Question 10 asked the students for their suggestions on how this type of quiz could be improved. A few students recommended that this type of quiz never be given again. Most students, however, provided constructive criticism. In Trial 1, students suggested there should be fewer errors to find and/or more time should be given. Having to correct the problem requires more time than provided. Some students suggested providing the erroneous solution in one column on the page and leaving the other column blank for solving the problem themselves. Then they would compare the two solutions to find the errors.

In Trial 1, students suggested providing a longer problem as a homework assignment, rather than a graded quiz. One suggested limiting errors to the free body diagram, the evaluation of given data, and theory. Some students recommended organizing the solution in a step-by-step fashion, possibly numbering each line of the solution. Another recommendation suggested giving the correct answer to determine if all errors have been found and the proper corrections made. One student suggested presenting the problem and solution on the board or with an overhead projector since it is easier to see and detect the errors as the problem solution is being developed.

One of the most important suggested improvements from Trial 1 was to show an example to the class illustrating exactly what is required, prior to using this type of problem on an assignment or quiz. Students are often fearful and have difficulty when trying something different from what they have done traditionally. An example of syntax error analysis done together in class will help ease their fears. In the example it should be indicated whether or not errors carry through the problem and whether corrections to the problem must be made.

Some of the suggested improvements were implemented in the in-class quiz given in Trial 2 and in the take-home quiz used in Trial 3. Student responses and comments for Trials 2 and 3 indicate the learning experience has improved. Additional trials planned for Spring 2000 will attempt to assess if the problem solving skills have improved for students who participated in Trial 2.

V. Conclusions

The "syntax error analysis" concept has evolved as a way to develop student skills in critically reviewing and checking calculations for errors.[1] Engineers and engineering technologists will review calculations for errors in industry. Skills required to solve these problems include problem interpretation, diagnosis and attention to detail.[8] Development of skills necessary to approach these problems can be addressed by incorporating appropriate problems in the undergraduate engineering curriculum.

Syntax error analysis trials were conducted using in-class and take home quizzes. Student feedback obtained using a questionnaire was used to improve subsequent trials. Based on the results of these trials and student comments, the following recommendations regarding the use of syntax error analysis as a problem solving technique in engineering and engineering technology courses are provided.

1. Clearly indicate to the students the format, the number of errors to be identified, whether or not errors carry through the problem, and what they will be expected to do on the problem.
2. Since students are not familiar with this type of problem, presenting an example in class is essential.
3. The number of errors should be reasonable for the length of problem and time provided.
4. Use errors that test knowledge and understanding of theory.
5. Avoid hidden math errors.
6. Provide an orderly solution with adequate blank space for students to do their own calculations or problem solution.
7. Provide an adequate amount of time, but stress to students that in industry, a limited time is usually allocated for checking calculations, and a complete reworking of the problem is not feasible in many cases.
8. Obtain and utilize student feedback to improve the format and learning experience.

Including syntax error analysis problems in the undergraduate curriculum can help engineering and engineering technology students develop the basic skills necessary to solve these types of problems in industry.

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