AC 2007-3038: CSI (CRASH SCENE INVESTIGATION): AN INQUIRY-BASED LEARNING PROJECT

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CSI (Crash Scene Investigation):
An inquiry-based learning project.

Introduction

Student-centered instruction has been shown to lead to increased motivation to learn, greater retention of knowledge, deeper understanding and more positive attitudes toward the subject being taught[1]. Student-centered instruction includes inductive learning (having students confront problems before they are given all the material needed to solve them), active learning (replacing some lecturing with participatory exercises done by individuals or small groups in class), and cooperative learning (having students complete some assignments in teams).

Students also require communication, writing and critical thinking skills in order to succeed in the workplace. Integrating writing and other critical thinking activities into a course increases students' learning while teaching them skills for posing questions, proposing hypotheses, gathering and analyzing data and making arguments[2]. Principles for supporting critical thinking include:

- Problems, questions, or issues are the point of entry into the subject and a source of motivation for sustained inquiry
- Instructor balances challenges to think critically with support tailored to students' needs
- Courses are assignment-centered rather than lecture-centered
- Students are required to formulate and justify their ideas in writing or other appropriate methods
- Students collaborate to learn and stretch their thinking.
- The developmental needs of students are acknowledged and used as information in the design of the course.
- Instructors make standards explicit and then help students learn how to achieve them.[3]

Unfortunately, the traditional engineering lecture emphasizes reliance on the instructor for the delivery of facts and principles rather than teaching students what solving real-world problems involves –analyzing and synthesizing the best available data, making assumptions and simplifications when necessary, and recognizing the limitations of the analysis. Many instructors perhaps would like to include more of the above-mentioned principles into their classes, but feel large undergraduate class sizes and difficult course content prohibits them from taking the time away from their traditional lectures.

The purpose of this is paper is to detail how a real-life forensic engineering problem, technical report writing and student-centered, inquiry-based learning concepts were incorporated into the weekly activities and term project for an engineering mechanics class. With the development of an appropriate problem, the project structure could be incorporated into any class. Techniques for marking engineering reports without significantly increasing instructor workload are also discussed.

Assignment outline

Students analyzed a car accident and occupants' injuries and wrote an engineering report on which car was at fault and whether the passengers were wearing their seat belts. The problem was solved in stages as students learned the necessary concepts. The report was also written in stages and iterations in order to improve the students' technical writing skills.

In the second week of classes, students were presented with problem and given a hand-out which included:

Problem Description
You have been called upon as an expert witness to analyze a car accident. The passenger of the bullet car, Faye Kinitt, is suing the driver of the bullet car, Lou Scannon, for her injuries. The lawyer for Mr. Scannon would like to know whether or not Ms. Kinitt was wearing her seat belt at the time of the accident, as she claims.

The lawyer requests a full report summarizing your calculations and reasoning by April 18. Excerpts from a police report and medical reports are attached.

Project Objectives
- To solve a real, complex engineering problem using the concepts presented in this course.
- To learn that real-life problems are typically open-ended without a unique solution, unlike the problems in textbooks.
- To use critical thinking skills to determine what data is required and appropriate to solve the problem, and to justify your analysis.
- To be able to explain the necessary mechanical principles in everyday language that a non-engineer can understand, as well as using calculations and diagrams.
- To justify your decision in a concise and persuasive technical report.

Project timeline
The problem will be broken down into components corresponding to material presented in class. These components will be incorporated into the weekly assignments. A list of topics includes:
- Impact and momentum
- Energy
- Moments of inertia
- Rigid body kinematics
- Rigid body kinetics
  (see the course outline for approximate dates for these topics)

- Shortly after each part of the problem is assigned, there will be a class discussion about what additional information is required to solve the problem, at which time this data will be provided by the instructor.
- The analysis and discussion section (including corresponding appendix) for each part of the problem will be due 2 weeks after that part is assigned. Calculations and reasoning will be given a mark at this time (50%), however only comments will be provided for the

writing. This feedback is intended to give each student a chance to improve their writing, and then compile and submit the entire report at the end of the semester.

- Please note that general comments will be made about tone of writing, organization and clarity of logic, however spelling and grammar mistakes are the responsibility of the student. An “X” will be placed beside each line with a spelling or grammar mistake and students are responsible for finding and fixing those mistakes themselves.

Report format

The report should be professional, well-organized and include the following sections:

- Title
- Summary Repeat the pertinent sentences from the analysis section at the beginning of the report so that someone who doesn’t want to read the whole report can find your conclusions quickly.
- Incident as Understood Include a brief description of the accident including time, date, names, location and directions. You might finish with a sentence like “I have been asked to investigate ______ and report on _____.”
- List of Available Information List the information you reviewed in making your analysis. This protects you in case further data later becomes available that would have resulted your making a different conclusion.
- Summary of Relevant Information Repeat or quote the relevant particulars of the accident and medical information that you use in your analysis.
- Analysis and Discussion Describe, in words, the basis of your opinion including assumptions. You should probably have smaller subsections for each part of the problem. Refer to an appendix for each subsection which will list assumptions and include a diagram, calculations and references.

Marking

- Note that, as in real life, there may not be a single right answer to this problem. Your work will be marked more on the quality of evidence and reasoning you provide to support your argument. (30%)
- Assumptions and calculations (20%)
- Report organization and quality of writing (30%)
- Grammar & spelling (20%)

CSI: CRASH SCENE INVESTIGATION

Motor Vehicle Accident Incident Report Form

This report must be filed within 24 hours of incident

Date of Accident	Day of the week	Hour
mo 01 day 15 year 03	☐M ☐T ☐W ☐R ☐F ☑Sa ☐Su	~ 23:30

I. Incident information

Number of Vehicles Involved:

Impact Type:	Involved collision with:
☑ front to rear ☐ side impact ☐ sideswipe ☐ head-on ☐ rollover ☐ other	☐ animal ☐ parked vehicle ☐ fixed object ☑ vehicle in traffic ☐ pedestrian ☐ left road - no impact ☐ bicycle
Nearest intersection: CROWCHILD TR +5AVE NW	Did incident occur at intersection: ☑ yes ☐ no
Weather: ☑ clear ☐ foggy ☐ cloudy ☐ rain ☐ snow ☐ ice	Light conditions: ☐ daylight ☑ dark - road lighted ☐ dusk/dawn ☐ dark - road unlighted

Road Surface: ☑ dry ☐ wet ☐ icy ☐ snow

II. Bullet vehicle information

Driver's full name: LOUIS DAVID SCANNON

Driver's license: province ALBERTA # 130572-338	VIN #: JJKLMMN

Vehicle make and year: 1987 Jeep
model: Wrangler YJ style: colour: red

License plate: ABC 123	Vehicle drivable after accident: ☑ yes ☐ no

Approximate damage amount:
☐ \$0-\$1 000 ☐ \$1 000 - \$5 000 ☐ \$5 000 - \$10 000
☑ \$10 000 - \$25 000 ☐ >\$25 000

Description of damage:

- approx 45 cm crush to front bumper + hood

III. Target vehicle information

Driver's full name: WILMA JANE CARGOUGH	
Driver's license: province ALBERTA # 136745-567	VIN #: JAKBLCM
Vehicle make and year: 1985 Ford model: Escort style: hatchback colour: black	
License plate: XYZ 890	Vehicle drivable after accident: ☐ yes ☒ no
Approximate damage amount: ☐ $0-$1 000 ☐ $1 000 - $5 000 ☐ $5 000 - $10 000 ☒ $10 000 - $25 000 ☐ >$25 000	

Description of damage:

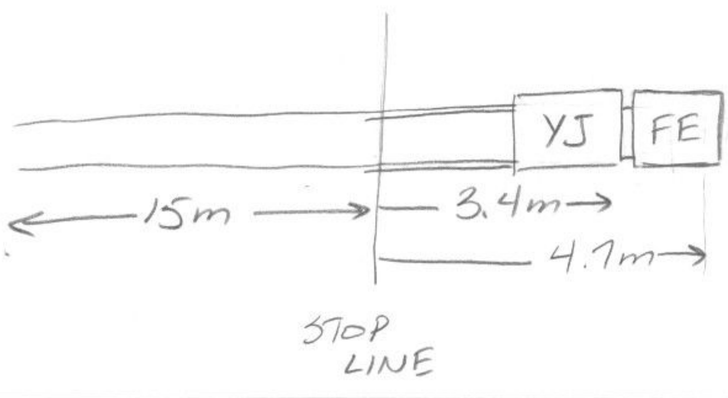
- approx 60cm crush to back bumper + hatch
- rear windshield shattered

III. Accident description

Description of evidence at scene:

- FORD ESCORT WAS STOPPED AT RED LIGHT SOUTHBOUND ON CROWCHILD
- JEEP YJ REAR-ENDED ESCORT

SKID MARKS MEASURED AT SCENE:



IV. Sign

I believe the information provided above to be accurate and correct:

Sign: [signature] Title: Const. Date: 01/15/03

Use additional sheets as necessary if more than one target vehicle.

Assignment Part Ia

After an initial class discussion, students decided that in order to figure out if Faye Kinnitt was wearing her seatbelt, they would need to have an idea of the change in speed of the bullet car (the Jeep YJ) during the impact. They were told to write (in a sentence or two) how they planned to solve for the change in speed, and list the additional data they needed to solve.

Results

Having learned particle kinetics in class, the students generally knew that they would use those equations to solve, however they were unused to receiving a problem where all the necessary information was not already given. Several class and after-class discussions helped to get them started and most of them eventually figured out they needed to know masses and coefficients of friction.

Assignment Part Ib

After class discussion, the students decided they first needed to figure out how fast Lou Scannon was driving when he hit Wilma Cargough. They were asked to provide a written explanation of this estimate (with calculations in an appendix) including assumptions made, after being given the extra data they described in Part Ia.

Results

As textbook problems are usually very simplified, students often do not need to make many assumptions and many only reported one or two. A class discussion afterwards generated a list of more than 10. Also, as this was their first attempt at technical writing, their style was typically not very good. Some examples of poor writing style include:

- "First, I used the coefficient of friction and mass to find the deceleration, then I calculated…"
- "By Using the Conservation of momentum Formula which is a formula that is proven to work by Engineers and Scientists all over the world such as our great knowledgable professor [instructor name] at [institution name]."
- "First up is the Jeep. Sum all the forces acting on the Jeep to find out deceleration rate…"

Feedback and examples of how to improve writing style were discussed in class. Individual assignments were marked for the calculation accuracy and given feedback for writing style, and then students were asked to compile a report with all sections (title, summary, incident as understood, etc.) completed as much as possible based on the problem to date, and hand it in with their previous assignment. At this point students could increase their quality of reasoning mark, and get feedback on their report organization.

Assignment Part II

After the students had learned particle work and energy, a new twist was added to the assignment. They were asked to re-calculate how fast Lou Scannon had been driving, using work and energy equations. Actual crash test data for a Jeep Wrangler YJ was provided.

However, the students were warned that this was for an impact test where the Jeep struck a fixed concrete barrier, not a parked car which subsequently slides. Therefore, using the principle of work and energy, they were asked to discuss (in a short paragraph) how the crash test results could be used to support or not support their previous calculations. If not, which result did they think were more reliable?

Results

Students had difficult with this section as it turned out that the work and energy calculation resulted in a higher impact velocity for the Jeep (it was speeding at time of impact). They had never been exposed to a problem where they could come up with two possible answers before. They also had difficulty explaining their reasoning in clear, concise and accurate language. One example of student writing is:

- "As a Jeep wrangler hitting a barrier and being crushed 17 inches takes a particular amount of energy, that energy is kinetic energy is lost into the force that's crushing the jeep 17 inches, in the real life case, when the jeep hit the parked Ford focus, the kinetic energy is lost in the crush force plus more energy is needed to keep both cars in motion".

Students were again given a chance to revise their work based on individual feedback and class discussion, and receive an increase in their quality of reasoning mark.

Assignment Part III

After covering rigid body kinematics and kinetics in class, students were finally asked to estimate the velocity relative to the jeep at which Ms. Kinnit's head may have hit the dashboard. They were told Ms. Kinnit sustained injuries to her knees, hips and head during the accident, but not her chest. Her knees and forehead were badly bruised and she received a concussion. Finally, given all the evidence, did they think Ms. Kinnit had been wearing her seatbelt and why? Again, additional data was given and students were to report any assumptions made. This last part of the assignment was submitted with a full report.

Results

Quality of technical writing had vastly improved in the students after having made so many revisions and receiving feedback, as well as overall report presentation and format. They struggled in their decision as to whether or not a seat belt was worn, but in the end it was a difficult calculation with so many assumptions that a "yes" or "no" answer was accepted as long as the students could provide a reasonable argument. The fact that there was no exact correct answer to this problem was a real eye-opener for the students, as engineering problems, particularly forensic car accident analysis, are often a "best guess".

Discussion

Students initially were less than enthusiastic about having to do work other than solving textbook problems and memorizing equations for an exam. However, the project taught them research and writing skills, and that real-life problems are complex and normally do not have a unique answer. End-of-semester feedback was extremely positive as the project ultimately engaged students in the course material. A quantitative analysis has not been performed to determine whether the project increased students' understanding of the course material, however since the course did not previously involve any technical writing or solving of open-ended, real-life problems, it can be said that the students skills in these areas improved. Overall course ratings went up and comments included:

- "I really enjoyed this class. It made me think of real life situations. My favorite part of the course would definitely be the CSI project. I did not think we had enough knowledge at this point to provide reasonably accurate calculations and reasoning for a case like a car accident."

Overall, this project incorporated all the principles for supporting critical thinking, and stimulated student interest in the course as well as engineering in general. Technical writing skills were coached without a heavy marking load for the instructor by using guided discussions, critiquing sample solutions and papers, breaking a long assignment into stages, and stressing revision and multiple drafts. The project was worth 10% (5% was subtracted from the weight of two midterms) and the stages of the project were incorporated into regular weekly assignments, therefore overall student workload did not substantially increase, there were minimal changes to the previous course weighting scheme, and there was no loss of course content. With the appropriate real-life problem, this assignment format could be used in any engineering or science class.

Key factors that made this project such a success included:

- Finding a problem that incorporates more than one topic from the course and does not have a unique solution,
- Explaining the expected outcomes of the assignment (real-world problems, writing and critical thinking skills, instructor is not the absolute source of knowledge),
- Using class discussions to teach students how to approach problems rather than providing a perfectly constructed problem,
- Showing examples of student work and coach writing and reasoning skills,
- Reducing other course work such as textbook assignments and quizzes,
- Adding humour to course work (the students didn't notice this until the end of the semester when someone finally said "Lou Scannon", "Faye Kinnit", and "Wilma Cargough" out loud!).

Bibliography

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3. Kurfiss, J.G. "Critical Thinking: Theory, Research, Practice, and Possibilities." ASHE-ERIC Higher Education Report No. 2. Washing, D.C.: ERIC Clearinghouse on Higher Education and the Association for the Study of Higher Education, 1988.