Reducing the Friction in Fluid Mechanics? Integrating Educational Psychology with Engineering Education

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Abstract

This paper presents findings from a pilot study designed to bring principles of educational psychology into engineering education with the specific goal of improving student learning. Traditionally, upper-division undergraduate courses in engineering have been taught with a lecture-oriented, teacher-centered methodology, but educational research findings urge engineering educators to switch to more student-centered instructional practices. The instructors in this project worked together to address these issues in a ways that reflect the current trend toward psychologically active learning in engineering education that includes new ways of presenting the required information in ways that students responded to. Early results show success for engineering students with increased awareness of their own levels of learning, and survey data revealed that the students appreciated these curricular modifications.

Introduction

The discipline of educational psychology is founded on the ideas of performing, analyzing, and using current classroom research to understand more about student learning and use this knowledge to promote greater levels of learning in the classrooms. Engineering educators can then use this research base in educational psychology to improve/enhance student learning in undergraduate engineering courses. While many engineering educators understand and agree with this call to action, many are unsure about how to go about promoting active, student-centered learning environments in their own classes. Many also wonder if content will suffer due to the integration of these “softer” strategies.

This paper reports the findings of two engineering educators from The University of Memphis and The University of Kentucky who worked together in a team-teaching situation to integrate principles of educational psychology and research with engineering content. The primary goal was to increase engineering students’ awareness of their own levels of learning in an upper-level Fluids course at the University of Kentucky. The instructors in this project addressed these issues in a variety of ways that reflect the current trend toward psychologically active learning in engineering education. Examples include redesigned lab assignments focused on authentic engineering situations, customized programming instruction, redesigned tests which considered student perceptions, and the creation of an online journal to encourage continuous student feedback. These concepts were integrated with an ongoing communication component throughout the semester.

Background

A brief review of current research in engineering education reveals that many of our colleagues across the nation are already using research in cognitive learning theory in their classrooms. Instructional

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methodologies that focus on authentic tasks have been widely popular in primary and secondary education for several years, and some university educators are modifying their methods to include product-based activities. Oklahoma University's NSF-funded "Sooner City" project represents a multi-year, multi-disciplinary implementation of curricular change that incorporates active and collaborative communication between student groups and engineering instructors at the undergraduate level, and a review of their publications regarding their work shows that they are reporting remarkable success with these strategies (Kolar & Sabbatini, 1999). Likewise, the April issue of *Journal of Engineering Education is* devoted to discussing integrated curricular issues, and while each of these researchers uses a different approach, all share the common goal of improving student learning. Many of these innovations are also based upon the educational theory of constructivism, which emphasizes linking new conceptual knowledge to previous knowledge in very explicit manners in order to provide a solid system of educational "scaffolding" for student learners.

Most of the current curricular modifications are based on primary principles of cognitive educational psychology that urge educators to focus first on individual learning styles and then on curricular delivery (Kolb, 1984; Bloom, 1956; Randolph, 2000). In addition, the most successful programs are those which employ a variety of approaches designed to work in tandem to appeal to different learning styles. Randolph's (2000) recent examination of Kolb's (1984) and Bloom's (1956) ideas regarding individual learning styles suggests that engineering educators should design curricular methodologies centered around the needs of the students. At the same time, Randolph proposes that writing can be used as a powerful tool for learning by appealing to these different learning styles when the instructor considers more psychologically active forms of writing. Suggestions include asking students to write for specific, authentic audiences (such as potential clients), and creating informal writing assignments that allow students to apply new content knowledge to specific engineering problems (Randolph, 2000). Finally, the literature contains multiple examples of success with group-based or collaborative learning groups, we tested some of these examples with modifications of our own to integrate concepts, theories, lab experiences, applications, and ABET's communicative focus to help our Fluids students increase their levels of learning. From the literature review, we elected to focus on three main areas of modification as they relate to increased student satisfaction with the course and an increase in levels of student learning: our assignments, our evaluation of the assignments, and our communication levels with our students. While we focused on these three areas, we adjusted other aspects of the class (ie, exams) as needed.

Methodology

Course Foundation for CE441

The rationale behind choosing to focus our research on this particular class is simple: Scott Yost, an Assistant Professor in Civil Engineering at The University of Kentucky, had been teaching this course for several years. He reported increasing levels of frustration and stress associated with the class that manifested largely in student complaints: CE441 had too much content, too many assignments, and not enough time in the day to get these things accomplished while trying to understand the material. As the instructor, Yost agreed that some of these complaints were valid, but he was interested in a way to teach the same amount of material in a way that would increase his students' understanding of the concepts and increase their satisfaction levels with the class itself.

Prior to the Fall semester of 2000, Yost had required 4 individual projects for each student which required a 1-2 page write-up, 6-10 pages of supporting numerical data and charts, and some form of a deliverable (a design or a program written specifically to solve a problem). Each project counted for 5% of the students' total grade in CE441 (20% total). In addition, there were 3 exams in the course, each representing 15% of the total grade (45% total). The remaining 35% were due to homework (25%) and class participation (10%).

After attending a presentation at the 2000 ASEE National Convention in St. Louis in June, 2000, Yost consulted Anna Phillips of The University of Memphis regarding the similarities between her previous work in team-teaching there and his needs in the 441 course at The University of Kentucky. They spent several sessions addressing the goals and objectives of the 441 course, and after careful consideration, they elected to reallocate the point totals for the 441 course in the following manner: the four projects would remain, but their focus would shift to a group-based project of three-person teams. In order to account for the increased size, the projects would include 7-minute group oral presentations. These presentations would be videotaped to offer feedback to the students on their communicative proficiency and their technical skills. The course grading was redistributed to reflect the new strategies. The new allocation of points meant that each project accounted for 7.5% of the students' semester grade (30% total). Of this 7.5% project contribution, 2.5% were for the group oral presentation. Next, the exam values were examined and it was elected to offer all three exams, but to present the students with the option of keeping the best two of the three exams, so these point totals now accounted for 36% of the total grade. Homework was encouraged to be group-based and it represented 16% of the total course grade. Finally a new communications component was integrated into the course curricular design in the form of an online journal, worth 10% of the grade on a pass/fail basis. The remaining 8% went to class participation.

Each of these changes was based on a combination of previous research in engineering education and previous experience in redesigning instructional methodologies used in engineering instruction at The University of Memphis. The overall purpose of the research was identical to previous research in this area: the instructors wanted to apply previous findings to new classroom applications with the goal of increasing student satisfaction with the learning environment, and by doing so, possibly increase levels of student learning at the same time.

The previous explanation has focused on our rationale for choosing this particular course for our pilot team-teaching study, and the following sections discuss the actual curricular modifications we made in the classroom. Although much of our research has been summarized in order to stay with ASEE's guidelines for conference proceedings, both authors are happy to provide detailed examples and supplementary material for any of the modifications or assignments discussed in this project.

Assignment Modifications

Our first task was to collect student feedback regarding current assignments, and to do this, we reviewed Student Evaluation Forms from Yost's previous CE441 courses for the years of 1996-1999. Findings reported that students liked the professor's style and classroom management, but disliked writing, programming, and the combined workload and reference books for the course. Again, to focus on specific elements of student learning, we did not change the type or amount of work, but instead rearranged and redesigned the instructional methodologies.

Since much of engineering is based on problem-solving strategies and design principles, it seems a natural progression to extend these skills to apply to actual situations students are likely to encounter when they graduate. In Educational Psychology, this extension is referred to as Constructivism, and it basically refers to providing explicit links between previous information that a student knows and new information that a student is learning. One way of incorporating constructivist theories that we have had success with is to take an existing assignment and reformat it based on a hypothetical audience (a client) and a hypothetical situation (the design/analysis). The left column of Figure 1 is an excerpt of an existing assignment that was essentially sound pedagogically, but extremely limited in its ability to translate/transfer skills to a workplace situation. This assignment represented many typical student complaints: it included a precise set of instructions for performing an engineering task, but it did not link the engineering concept to an outside/external application that the student might use as a practicing engineer. The concept of audience awareness was not addressed at all, rather, students were instructed to write summary memos to Yost as their professor.

The modified writing assignment varied the content to address a client and a specific situation, and it was designed and delivered in a format that is similar to what students would/will receive as practicing engineers. Basically, the students received a Request-for-Proposal in the form of a memo from a hypothetical engineering client describing an authentic engineering-based problem. Student groups were instructed to function as independent engineering firms and address these concerns just as practicing engineering firms would. They prepared client-focused technical reports supplemented with relevant numerical data, and they prepared 7-minute oral presentations of their findings for the hypothetical clients in which they demonstrated engineering skills and engineering analysis with communicative proficiency as well. The right column of Figure 1 represents an excerpt of these changes.

The major difference between these two assignments is that the authentically-based one prepares the student to assemble the same basic knowledge package as the previous assignment, but at the same time, it requests the information in a format and manner that is practiced by professional engineers daily. Students are not turning in teacher-centered research reports as is common in many undergraduate engineering courses; rather, they are preparing more of a "client-centered" document, which focuses on their skills and abilities as future engineers.

Grading Guide Modifications

Our second area of modification for the Fall 2000 semester is directly related to the authentically-based assignments, with the idea that if a student is going to prepare a product (design/analysis) and presentation for a client, the student should have access to the client's criteria for both product and presentation throughout the design process. While clients will seldom formally "grade" engineers on their products and presentations like professors do, clients do assess and evaluate both the product and the presentation, and for these reasons, this information is provided for the students. Criteria for evaluation is provided with the initial assignment, so there are no surprises in the evaluation phase of assessment. An example of our criteria for evaluation that accompanies the authentically-based assignment is presented in Figure 2. Prior to this formal criteria, the instructor used a more holistic approach by setting up a document template (Introduction/Background/Motivation, Procedure, Results/Discussion and Conclusions/Recommendations) and generic expectations within each section.

Online Journal Modifications

The third modification in our pilot project was to create an online journal to allow the students to offer feedback and ask questions about the class in an informal context. A separate online account was created, and students were asked to participate at least *4* times during the semester with feedback or comments or questions about the course. In return, the instructors answered these journal entries and were able to modify instruction based on specific areas of feedback received. Ten percent of the course grade was allowed for the journal entries, and these points were taken from previous homework and class participation grades. In order to promote convenience and encourage informality, the entries were not formally assessed or evaluated in any way; if a student submitted at least *4* entries, s/he received all *10* points.

Assignment Modification Findings

Surveys ($N=52$) were designed and distributed following each major lab assignment (project) in the course, and the reports revealed the students generally viewed the assignments as very positive learning experiences. For instance, on the first lab assignment, *50* of the students agreed with the survey statement: "I believe that this lab assignment includes the type of writing, analysis and presentation skills I'll be required to have as a practicing engineer." Slightly fewer students (*43 of 52*) agreed that "... this assignment reflected my knowledge...".

However, when asked to quantify their grades by using the instructor's evaluation rubric in a self-assessment, the students self-assessed grades resulted in an *88* (out of *100*) average. The instructor's actual grade resulted in an average of *82*. Looking at qualitative comments, the students liked the format and delivery of the extensive labs even though they were initially unfamiliar with required format. They believed that the assignments focused more on presentation skills than technical skills to the point that they would have liked more technical instruction. With the ongoing feedback throughout the semester, the assignments and instruction increasingly emphasized technical content. This paralleled the students' perceptions about making presentations.... they liked the idea because they saw the relevance, but hated doing them at first. This had changed dramatically by the last presentation where they knew what to expect. Finally, they appreciated the idea of writing in the expected professional format to a hypothetical client.

The final exit survey (*N=42, 10* students were absent during the survey) asked students to rate a series of statements on a scale of *1* to *5* (*1* = strongly disagree, *3* = neither agree/disagree, *5* = strongly agree). They believed "my written, oral, and presentation design skills were increased in this class" (*4.05*); they believed "the presentations will assist me in my professional employment" (*4.00*); and they believed "the writing assignments for this course reflected the kind of writing I will do as an engineer" (*3.86*). Overall, students agreed that they benefited from the type of communication presented in class.

Evaluation Modification Findings

Besides the final exit survey, several project surveys were collected in addition to the on going feedback from the online journal. Student responses to the criteria-based assessment forms for the projects were initially mixed, but by the end of the semester, they reported greater satisfaction with this type of system when compared to the systems they have encountered in other engineering courses. Responses to the first and second assessment forms indicated a fair amount of confusion associated with specific criteria (audience awareness and formatted heading requirements), and several students complained about the numerical breakdown of the divisions. The instructors worked together and reformatted the assessment rubric for the third and fourth assignments with significantly improved responses from students. The first two evaluation rubrics (see Figure 3) caused some confusion resulting in a *3.36* average (*5.0* scale) when the students were asked if "the evaluation of the lab assignments was fair and accurate" (this compares with a *3.88* average for both "the evaluation of the tests was fair and accurate" and "the evaluation of the homework assignments was fair and accurate"). However, overall the students agreed with the statement "I liked the criteria-based system of grading (the table) used for the written labs better than the traditional system of assigning a specific number with no comments/breakdown" (*4.10*).

Online Journal Findings

Near the beginning of the semester, the journal entries were rather reticent and distanced and focused mainly on elements of classroom content delivery and group dynamic problems, but many students indicated a willingness and an appreciation to try this new form of communication. By mid-semester, students were using the online journal more frequently to ask questions about writing requirements, project requirements, and presentation information, and instead of merely submitting comments, many students began actively corresponding with the instructors through the online journal format. Through both the journal entries themselves and the survey results, students reported surprise and satisfaction that their questions and comments were answered expediently and efficiently, and many of them reported that they believed "the online journal contributed to my opportunity to learn in this class" (*4.02*). Finally, the students thought this format was useful enough to recommend using it in the future with a *4.29* rating "would recommend the use of this type of journal for student-professor feedback in other courses".

Below are some excerpts from the journal. This first one illustrates the students' evolution to the format and requirements as the professors respond to their feedback. The second excerpt illustrates the acceptance of the format and the increased ability to learn. The last two talk about the overall value of the online journal format.

> *9/27/00: This second lab was better than the first. It was a lot of trial and error = busy work, but I like the idea of finding the best design and selling it to the client. I'm looking a little bit more forward to this presentation. I'm not as nervous anyway. I FEEL like we all have a better grip on this material than on the error analysis. That will make it easier to talk about. The competition aspect is a nice change too.*

> *9/20/00:I had an internship this summer and really enjoyed talking to everyone, but dislike working with one of the team members for a project. I understand the real life scenario involved in lab and really enjoy the memo/presentation format. This is 10,000 times better and more realistic than your simple lab report. So, in effect, I have changed my mind. But, for future reference (like next semester) I think it would be nice to allow the students, since a grade is on the line, to divide into groups with people they feel most comfortable with and would have less trouble arranging similar meeting schedules…*

> *8/24/00: I believe that online journals will help to foster better understanding between the lecturer and students. The traditional way for students to complete an evaluation form at the end of each semester is not effective enough. Instead, comments and feed backs should be done frequently throughout the semester. What's the point of evaluating a professor at the end of semester when they have a chance of doing it earlier and at the same time, it might also improve their class performances?*

> *9/21/00: First and foremost, I would like to express my gratitude toward you (and Dr. Yost) for trying this new approach to teaching in the college classroom. I can report that Dr. Yost seems to be trying really hard to live up to his end of the agreement, which has led to a much more pleasurable learning environment. This attitude has also spilled over into our Engineering Systems class (CE 421).*

Discussion/Recommendations

Of the three modifications, we believe the online journal was most effective in improving and promoting communication skills between students and faculty. A total of *52* of the *53* students completed the journal requirements, and about *31* students corresponded through the journal significantly more often than the required number of times. As instructors, it was helpful to have student feedback throughout the course so instructional and content modifications could be made as the students needed them, and even when the student feedback was not encouraging, it still represented communicative opportunities that might not have been possible otherwise. In fact, many of the students expressed relief/satisfaction with the two-instructor design of the journal that allowed them to correspond confidentially with one instructor and have the comments relayed or summarized to the other instructor anonymously because they feared that their identities might somehow influence their grades if their names were known. In addition, students seemed to have a sense of ownership in the course because they had direct evidence that their comments and feedback were being heard and responded to by both instructors. We believe this supports our original goal of improving student satisfaction with the course.

Regarding the other curricular modifications, our survey data indicate that the modified assignments and modified criteria-based evaluation systems contributed to an increase in student learning levels. From the qualitative student-generated comments we received, the students agreed that our teaching methodologies “contributed to their learning” while their “skills were increased”. An improved class GPA when compared to previous semesters also supports the premise of increased levels of learning.

To summarize, both instructors and most of the students were pleasantly surprised by such significant and positive short-term findings, and extensions of the project are currently being used at both universities. Yost and Phillips are again applying the same strategies to the Spring 2001 CE441 course taught at The University of Kentucky, and Phillips is working with a second engineering professor in a freshman-level Engineering Analysis course at The University of Memphis, and findings from the spring semester will be included in the conference presentation.

ANALYSIS AND DATA PRESENTATION

A. A table is needed to document the necessary computations to determine the velocity for each test condition. Note that the barge is *6 inches* in length. With the velocity, weight and impact force, graph F vs. V on a scatter plot. The use of several regression programs determines the relation between the force and velocity.

B. The form of the equation relating impact force to weight and velocity is

$$F = CV^aW^b$$

where F is the impact force, V is the velocity of the barge, W is weight of the barge and contents and C, a, and b are coefficients. Plot the Impact Force as a function of the velocity. Is there a trend? Confirm the hypothesis that $C=0.8$, $a=1.3$ and $b=-0.07$.

C. For this type of calibration effort, it is important to understand the relative error introduced into the experiment by the various measurements. Details of linear error analysis will be discussed in the lab. You will provide a detailed error analysis derivation as part of the computations. Assume for this experiment that the precision of the length was *+/- 0.05in*, the measurement of weight was *+/- 0.02 lbs,* the time was *+/- 0.0003 seconds* and the impact force was *+/- 0.0095lbf*. After performing the error analysis, compute how individual measurement errors translate into an error in the impact force for each data point. Which measurement is most likely to have an adverse effect on the experimental results? Is the variation in the impact force observed in the experimental data explainable on the basis of limited precision in the measurements (hint: include error bars on your F vs V graph)? Which measurement techniques would have to be improved, and what would be the required resolution, in order to improve the accuracy of the calibration? How does the error in F_{calc} relate to the error in F_{exp}?

D. Present your results in a concise one-page summary utilizing the graphs, error analysis and all computations as supporting documentation. Your audience is the primary issue (See audience profile discussion). The one page summary will be divided into three sections: background and motivation, results and discussion, and recommendations. Make sure you address all questions raised in this handout!

ANALYSIS AND DATA PRESENTATION

A. **Concept:** The form of the equation relating impact force to weight and velocity is

$$F = CV^aW^b$$

where F is the impact force (lbf), V is the velocity of the barge (ft/sec), W is weight (lb) of the barge, C, a, and b are coefficients. The precision of the length was *+/- 0.05in*, the measurement of weight was *+/- 0.02 lbs*, the time was *+/- 0.0003 seconds* and the impact force was *+/- 0.0095lbf*.

Application: Design a table to document the following computations. Note that the barge is *6 inches* in length.

- Plot the Impact Force as a function of the independent variables V and W.
- Is there a trend?
- Using multiple-linear regression with the linearized form of the equation, determine values of a, b, and C?

B. **Concept**: In any calibration effort, it is important to understand the relative error introduced into the experiment by the various measurements and their effect on the overall validity of the data. The error analysis documents how individual measurement errors translate into the total error in the impact force.

Application: Perform a linear error analysis to answer the following questions:

- Which measurement is most likely to have the greatest adverse effect on the experimental results?
- Is the variation in the impact force observed in the experimental data explainable on the basis of limited precision in the measurements (hint: include error bars on your F_{obs} vs V and W)?
- How does the error in F_{calc} relate to the error in F_{obs}?
- Is improvement in the experimental technique necessary so that the combined error in the measured independent variables (L, W, and t) are bound by the error in the measured impact force (F_{obs})?

WRITING ASSIGNMENT

The situation:

Practicing engineers often have to present complicated technical data to non-technical audiences, and for this report, your audience is Juanita Seagraves, Vice-President of Prefabricated Piers. Her company believes that prefabricated piers can be used instead of cast-in-place piers. However, to do this, they need to come up with an improved method of quantification of the impact forces on piers. Ms. Seagraves' company can avoid costly over-design expenses by developing a more robust impact theory and corresponding equation(s) to quantify the impact force on piers, while using greater quality control in the prefabrication process. Prefabricated Piers is planning some field tests and extensive laboratory work on scale models and would like feedback on the validity of their equation, as well as on the accuracy of collecting laboratory data.

The link to real-life engineering practice:

Your lab group functions as a consulting engineering firm, and the members of your group have received the attached memo from Ms. Seagraves requesting your assistance. Your group will work together to write a one-page memo with attachments reporting to Ms. Seagraves the results of your work. Your report should include three main sections: a brief background and motivation section, a results and discussion section, and your recommendations section. Present the information in language geared toward a non-technical reader, using your graphs, error analysis, and computations as supporting information. Finally, your group will organize, design, and present a 7-minute presentation to your client via videotape on __________________.

***Note:** The language of the memo is dense, wordy, and difficult, but this serves as an authentic example of what you would receive as professional engineers. While you can't change this, you CAN and SHOULD make your own report clear, brief and easy to follow.

Figure 1. Excerpt comparison of original (left) and revised (right) assignments.

CRITERIA FOR EVALUATION
Group name: ______________________
Group members: ______________, ______________, ________________, _______________

Audience Analysis
20 points/___

	Minimal (0-1 pts)	Adequate (2-3 pts)	Excellent(4+ pts)
Memo format			
Proper recipient			
Audience awareness			
Explanation of terms in plain language			

Content Analysis
30 points/___

	Minimal (0-3 pts)	Adequate (4-7 pts)	Excellent(8+ pts)
Background/motivation			
Results/discussion			
Recommendation			

Presentation of Data
30 points/___

	Minimal (0-3 pts)	Adequate (4-7 pts)	Excellent(8+ pts)
Use of graphs/charts			
Error analysis			
Computations			

Technical Writing Proficiency
20 points/___

	Minimal (0-1 pts)	Adequate (2-3 pts)	Excellent(4+ pts)
Clarity of writing			
Organization			
Grammar/punctuation			
Correct spelling			

Oral Presentation Analysis
50 points/___

	Minimal (0-1 pt)	Adequate (2-3 pts)	Excellent(4+ pts)
Appearance			
Introduction/participation of all members			
Connectives/ transitions			
Organization/ quality			
Extemporaneous delivery			
Language/voice			
Non-verbals			
Visual aids			
Conclusions/recommendations			
Time (+/- 15sec intervals)			

Comments:

Figure 2. Evaluation criteria for the first assignment.

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