THE REAL GATHERING STORM: INSTRUCTIONAL SHORT CIRCUITS CREATED BY A DIGITAL WORLD

Ronald J Hugo and Robert W Brennan

Schulich School of Engineering, University of Calgary

ABSTRACT

This paper explores the impact of student reliance on course textbook solution manuals. It shows that students are able to perform well on certain types of problems, yet lack a fundamental understanding of course material as demonstrated through the use of concept questions. This lack of understanding is most likely the source of disagreement between Engineering Educators and Industry Supervisors when evaluating Technical Fundamentals as reported by the ASME Vision 2030 task force report.

KEYWORDS

Classroom Cheating, Assessment, Peer Instruction, CDIO Standards 8 and 11

INTRODUCTION

In an effort to guide the evolution of Mechanical Engineering education in response to changes occurring within engineering practice, the recent ASME Vision 2030 project solicited feedback from academia, early career engineers and industry (Kirkpatrick et al., 2012). A total of 80 Mechanical Engineering (ME) department heads, over 1500 industry engineering managers, and 635 early career mechanical engineers were surveyed as part of this project. The global firms that participated in the survey were relatively large, with a median number of employees being 10,000. The survey results quantified the Strengths and Weaknesses of recent Mechanical Engineering graduates, with the survey results for Strengths shown in Fig. 1. Many of the categories evaluated in the survey map directly to the CDIO Syllabus, including Technical Fundamentals (1.2, 1.3), Problem Solving and Critical Thinking (2.1, 2.4), Experiments (2.2), Overall Systems Perspective (2.3), Interpersonal / Teamwork (3.1), Communication (3.2), and Design (4.3-4.6). Given the extensive nature of the data collection exercise, the results provide valuable insight for CDIO Standard 12 – program evaluation, albeit on a multi-institutional averaged basis.

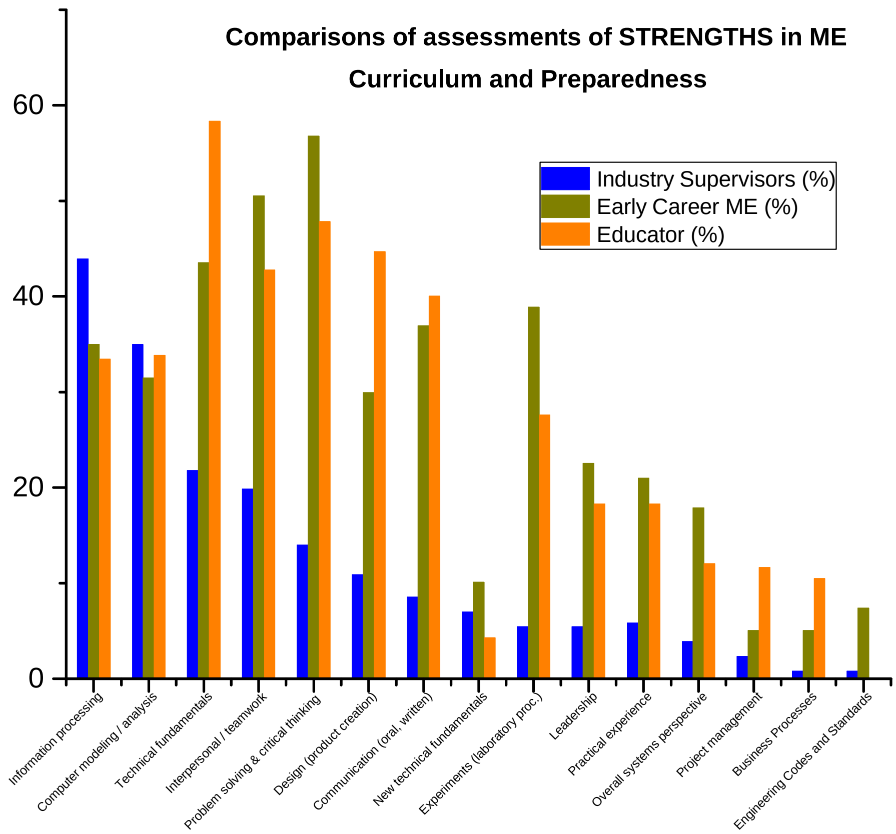


Figure 1. ASME Vision 2030 Data (Kirkpatrick et al., 2012)
Perceived Strengths in ME Graduates on a 1-100 Scale

Program reforms driven by the ASME Vision 2030 results will naturally first focus on areas of perceived weakness as reported by industry, with i) Practical Experience, ii) Communication, iii) Engineering Codes and Standards, iv) Overall Systems Perspective, and v) Problem Solving and Critical Thinking being reported by Industry Supervisors as the top five areas of weakness (Kirkpatrick et al., 2012). A second and perhaps more subtle opportunity for reform exists by carefully considering areas where there is a strong mismatch in opinion (20 or more points on the 100 point scale used in the survey) between Industry Supervisors and Educators. Points of disagreement are, in some respects, more important as they provide the opportunity to highlight areas where Educators have developed a somewhat myopic view of program quality. The results of this comparison are shown in Fig. 2.

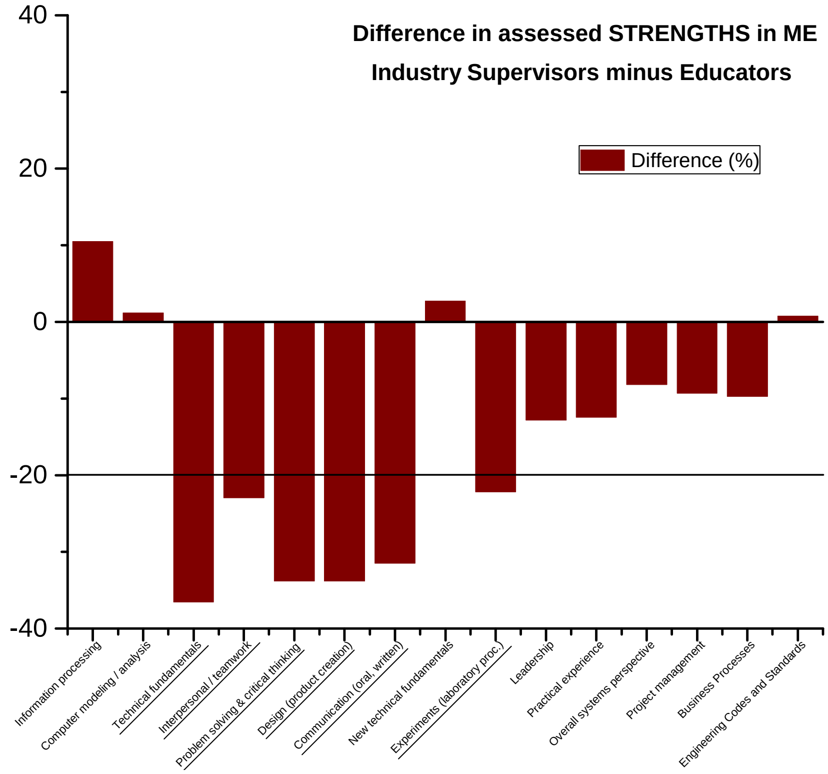


Figure 2. ASME Vision 2030 Data – Difference in Perceived Strengths in ME Graduates
Industry Supervisors minus Educators

As shown in Fig. 2, Engineering Educators are found to overrate by more than 20 survey points (in contrast with Industry Supervisors) the strength of graduates in six areas:

i) Technical Fundamentals (traditional ME subdisciplines);
ii) Interpersonal / Teamwork;
iii) Problem Solving & Critical Thinking (analysis);
iv) Design (product creation);
v) Communication (written and oral);
vi) Experiments (laboratory procedures).

The fact that Interpersonal / Teamwork, Design, and Communication result in disagreement is not overly surprising within the CDIO community given that these areas provided the original motivation for the formation of the CDIO Initiative (Crawley et al., 2007). What is concerning, however, is the fact that strong disagreement now appears in areas that were previously considered as a strength, namely Technical Fundamentals and to a lesser extent Problem Solving / Critical Thinking and Experiments. This paper will explore these areas of disagreement further using both observational as well as quantitative data analysis.

Research Questions:

Given the relatively strong disagreement between Industry Supervisors and Engineering Educators when it comes to assessing the strengths of ME graduates in areas such as

Technical Fundamentals, Problem Solving / Critical Thinking, and Experiments (Laboratory Procedures), the paper will use several measures to examine the performance of Mechanical Engineering students in a core Mechanical Engineering Thermodynamics course. The investigation examines student performance on concept questions that were administered weekly and performance on a final examination that included a mix of both review and new material questions. Through a combination of student performance and instructor observations, the sources of disagreement between Industry Supervisors and Engineering Educators are identified.

BACKGROUND

The Mechanical Engineering Thermodynamics course was delivered during the Fall 2013 semester which spanned 13 weeks from early September to mid-December. A total of 92 third-year (junior) Mechanical Engineering students were enrolled in the course. The course is the second in a two-course sequence taken by students in the Mechanical Engineering program, and course content includes three weeks of review of the previous Thermodynamics course followed by ten weeks of material that is new to the students.

METHODS

This section discusses the nature of the student sample, the instruments and measures used, and the procedures by which the instruments and measures were delivered to the student sample.

***Sample*:**

The first year for students in the Schulich School of Engineering is experienced as a common-core year. At the conclusion of the first year, students select their programs. Placement in programs is highly competitive and based on the students' first-year GPA (Grade Point Average). Mechanical Engineering has been a popular program choice for students, and the first-year cut-off GPA for the Mechanical Engineering program has averaged between 2.6 and 2.8 on a 4-point scale.

Instruments and Measures:

1) Instructor Observations

The course instructor (first author) was present for all Active Tutorials, the two semester exams, and the final examination. This was the sixth time that the course instructor had taught the course. The previous five offerings of the course were from 2001-2005, and there had been an eight year lapse from the last time that the instructor taught the course in Winter 2005. This provided an opportunity to compare student behavior from the 2001-2005 time period with student behavior in Fall 2013.

2) Performance on Weekly Assignments

A total of eight assignments were given during the duration of the course. Assignment problems were taken from the course textbook (Cengel et al., 2011) and the number of assigned problems ranged from three to twelve, with an average of six problems per assignment. One assignment problem per assignment was randomly selected and graded which counted as 10% towards the final course grade.

3) Concept Questions

The Fall 2013 course was taught in a blended format with lectures made available on-line. Normally, lectures would be 50 minutes in duration and held 3 times per week. Using the on-line blended format permitted flexibility with the regularly-scheduled lecture time. As a result, Active Tutorials were held once per week and usually on the days that an assignment was due. Active Tutorials typically featured five to six concept questions that pertained either to the assignment material or a review of material in advance of a semester exam. Student participation was recorded during the Active Tutorials using a personal response system, and the weight assigned for participation was 10% of the final course grade. Student answers were also recorded; although, performance was not reflected in the course grade.

4) Semester and Final Exams

The course also included two 50-minute semester or term exams (Exam 1 and Exam 2) that were open textbook. Each semester exam was worth 15% of the final course grade, and each exam consisted of two questions. Exam 1 involved two questions taken from a different textbook but of a similar style to the assignment questions. Exam 2 involved two questions taken from an earlier edition of the course textbook. The first question from Exam 2 involved the use of English units. Though English units were not specifically required to complete the assignments, students were informed several times that they were responsible for knowing how to handle questions involving English units. The second question covered a more theoretical aspect of the course that involved calculations on the performance of the Carnot cycle.

The 180-minute final examination was also open textbook, and it featured five questions. Two of the questions were “review questions” that assessed student understanding of foundational material covered in the prerequisite course and also reviewed during the first three weeks of the course. The remaining three questions pertained to “new material” that was covered during the remainder of the course.

Procedures:

In order to be consistent, the course instructor selected all of the assignment questions; designed / selected the concept questions and administered them during the Active Tutorials; and set and graded all questions for all examinations.

RESULTS AND DISCUSSION

Instructor Observations:

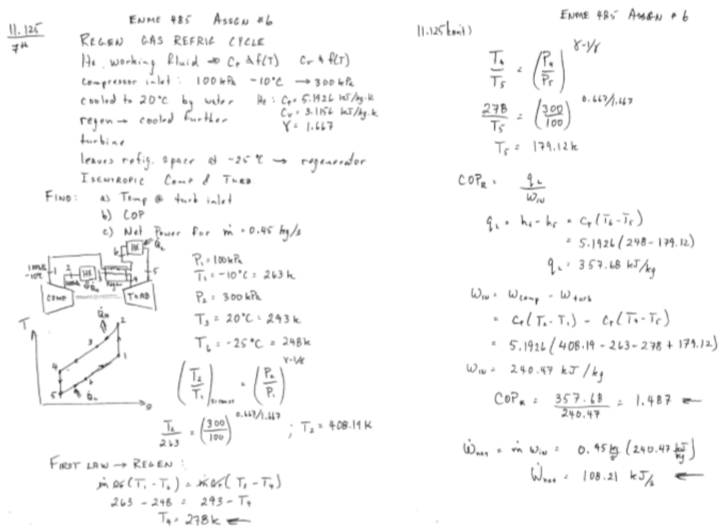
During the semester the course instructor noted a few changes in student behaviour from what had been observed when the course was last taught in 2005. The first change became apparent during the Active Tutorial on the day that the first assignment was due. When asked if they had completed the assignment that was due at the end of that day, only about 25% of the students raised their hands. When the instructor told them that they had better get working on the assignment as it was a long one (with twelve questions), the students laughed out loud.

During another of the Active Tutorials the students performed poorly on a question that they should have been able to answer had they read the textbook. When asked how many of them were reading the textbook, only about 10% of the students raised their hands.

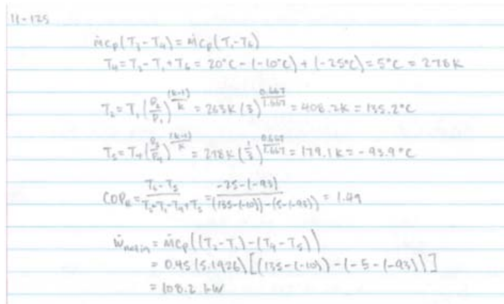
As the semester progressed, it was found that students rarely asked questions about the assignment problems. This was a drastic change from when the course was last taught during the 2001-2005 time period. At that time, demand for support was so great that students often lined up outside of the professor's office seeking assistance with the assignments. In contrast, during 2013 it was found that students were mostly asking questions about problems that had not been assigned. Finally, one student e-mailed the professor asking about the solution to one of the questions that had been assigned. When the professor responded that the solution for this question had not yet been posted, the student countered that he had a question about the solution as found in the solution manual to the course textbook. It was at that point that the student came forward and explained in person to the professor that the majority of students have access to solution manuals to nearly every textbook being used in the Engineering program.

Performance on Weekly Assignments:

With the above observations in mind, the course instructor started to monitor more closely student performance on the assigned questions. An example of a solution to an assignment problem that was computed separately by the instructor and a student is shown in Fig. 3. The instructor's solution required two pages to complete while the students solution required only eight lines, without the need of a process diagram or schematic. Solutions submitted by students in this condensed style provide strong evidence that the solution was likely copied from a solution manual. It is highly unlikely that the student rewrote the solution in a compact form to save paper or reduce the amount of material that the professor would need to grade.



(a) Instructor solution



(b) Student solution

Figure 3. Solution to an Assignment Problem

A final opportunity to monitor student behaviour arose when it was found that there was an error in one of the assignment problems in the solution manual. The course instructor took this opportunity to grade the assignment himself, and out of the 89 assignments submitted, 89 had the same incorrect answer as the solution manual. Consequently it was concluded that all students in the class were relying heavily on the solution manual to do the assignments, and most likely also to study for exams. This type of behaviour is not entirely new, but the degree to which it has been adopted by students has increased. It is possible that one factor could be that solution manuals are now distributed by publishers in Adobe Acrobat files, expediting their access by students via file sharing websites (Widmann, 2006; Young, 2010; Perez-Pena, 2012).

Concept Questions:

As mentioned earlier, having adopted a blended delivery model for the course enabled the use of Concept Questions and Peer Instruction (Mazur, 1997) during Active Tutorials. Student performance during Active Tutorials was monitored using Turning Technologies personal response systems. Performance on Concept Questions during the first Individual attempt versus the second Peer attempt is shown in Fig. 4. As expected, student performance is seen to increase during the second attempt after consultation with peers. One could surmise that in most cases student performance increased given the opportunity to reflect for a second time in a collaborative format knowing that the first individual attempt produced an incorrect response. It was also found that student responses during the first Individual attempt ranged from 25% correct responses (essentially guessing given that most questions often only had four answers) to approximately 65% correct responses.

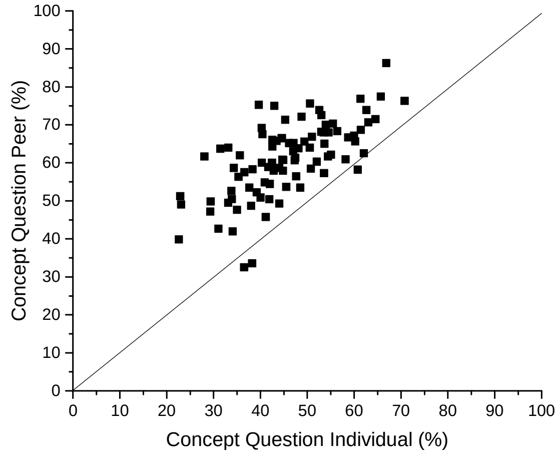


Figure 4. Concept Questions – Peer Performance versus Individual Performance

Semester and Final Exams:

As mentioned earlier, two types of questions were given to students during the examinations**:** 1) Familiar / Expected questions, and 2) Foundational / Theory questions. The first type of question featured problems that were very similar in style to the assignment problems. Thus, these are referred to as "Familiar or Expected" problems. The other type of question involved either review problems or problems with a small but subtle difference from the assignment problems (examining performance of a gas power cycle as discussed in the textbook and lectures but not asked on an assignment, for example). This second type of problem is referred to as a "Foundational or Theory" problem. It is noteworthy that this second type of problem appeared to create confusion for some of the students. That is, during the final exam several students asked the instructor if he could tell them what chapter these questions were from so that they could gain their bearings and solve the problems.

Figure 5 illustrates that students found the Foundational / Theory questions challenging, as evidenced by the cluster of data points in the upper left hand corner of both plots. There are a number of potential reasons for this poor performance. The first is that students rely heavily on the solution manual while solving assignment problems, and this transforms the learning process from the traditional (Fig. 6) to a short-circuited learning process (Fig. 7). In other words, students are studying by copying and/or memorizing the solutions as provided in the published solution manuals. In the past, students did not have the same level of access to solution manuals. Instead, they needed to develop their own understanding of the concepts in the textbook in order to apply their learning to the process of solving problems assigned by the instructor. As a result, the present approach to learning and studying shortens the length of time required by students to fulfill the assignment requirements. However, it also circumvents the learning process that would encourage students to actually develop a deeper understanding of the basic and fundamental concepts on their own. Furthermore, this reduction of time on task has a negative impact on the development of the Component Skills (Ambrose et al., 2010) that are necessary for problem solving.

Similarly, students also prepare for exams with the assistance of the solution manual. This approach focuses on memorizing the solution technique as opposed to understanding the underlying concepts. Figure 8 shows the relationship between student performance on

Concept Questions and on the more challenging “Foundational or Theory” problems. The correlation between performance on Concept Questions and an ability to solve Foundational or Theory type problems indicates that students perform in a similar manner on these two types of questions.

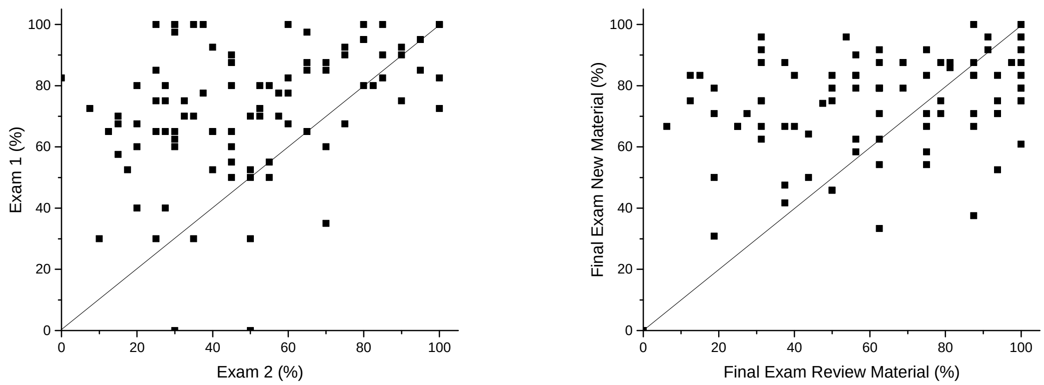


Figure 5. Familiar / Expected Exam Questions versus
Foundational / Theory Exam Questions

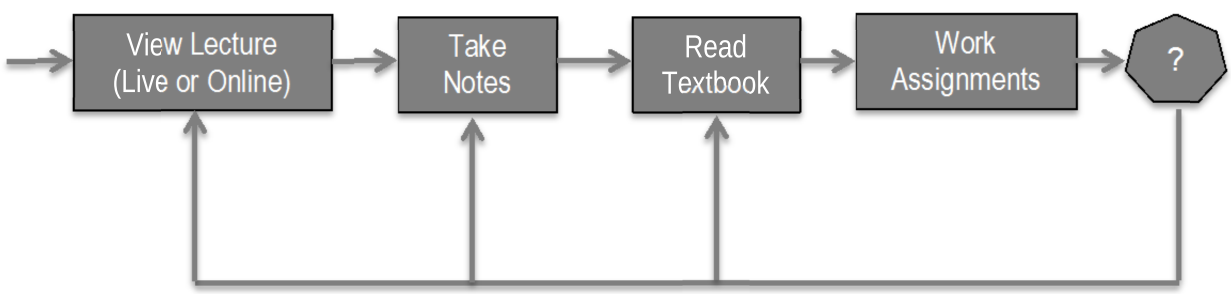


Figure 6. Traditional Steps to the Learning Process

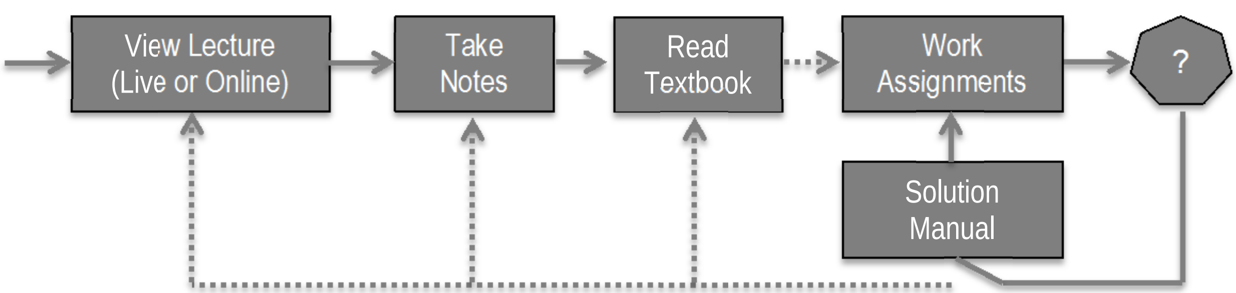


Figure 7. Short-Circuited Learning Process

Figure 9 shows that when students are given problems that are similar to what they have seen on the assignments, their performance improves. This phenomenon is a logical expectation and not at all surprising. Given that examinations often have questions that are similar to the assignment problems and usually cover the most recent material, students are typically able to perform relatively well on exams. This does, however, demonstrate that their understanding of the material is somewhat superficial given that performance is dependent upon the nature of the question asked. An inability to perform well on Concept Questions or questions involving the understanding of fundamentals (Foundational / Theory questions) is most likely what has caused Industry Supervisors to rank Technical Fundamentals lower than Educators, as discussed in relation to Figures 1 and 2.

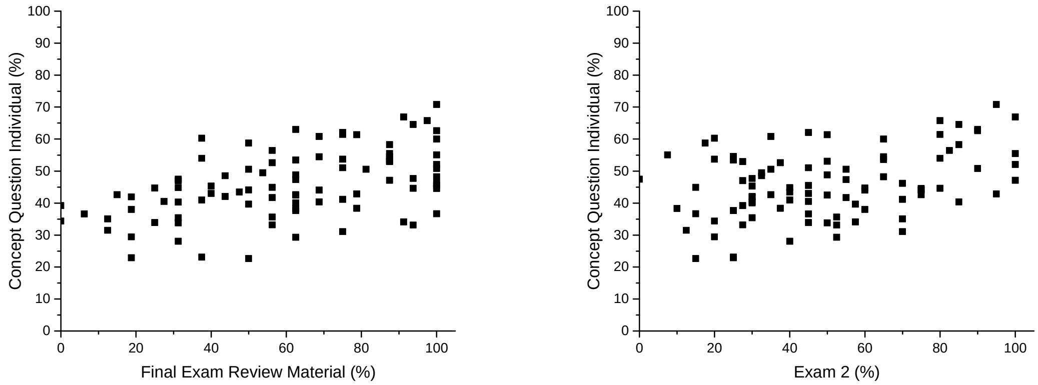


Figure 8. Concept Question Performance versus
Foundational / Theory Exam Question Performance

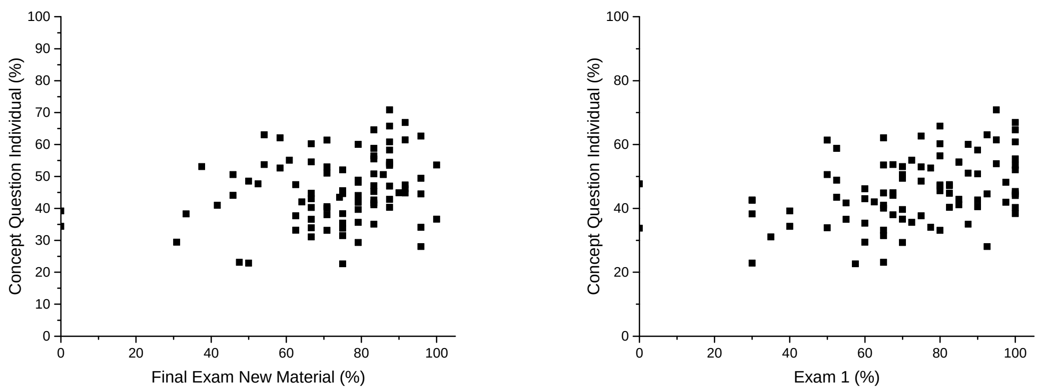


Figure 9. Concept Question Performance versus
Familiar / Expected Exam Question Performance

Given the reliance on solution manuals, students are spending less time on practice which has a negative impact on performance (Ambrose et al., 2010). In turn this reduces their development of successful Problem Solving and Critical Thinking skills. Although not discussed in this paper, similar shortcuts exist with laboratory write-ups. In this case, students rely on electronic copies of old laboratory reports, and copy from these reports instead of writing their own reports. This strategy has a negative impact on both their understanding of Experiments and on their ability to Communicate in written form. All of these deficiencies result in the noted disagreement between Industry Supervisors and Engineering Educators in Fig. 2. In other words, Educators would surmise that students have a competent understanding of fundamental theories based on adequate or superior performance on assignments and exams, particularly if these assignments and exams replicate what is found in the official course textbook and corresponding solution manual. At the same time, given that on-the-job performance requires a deeper understanding of fundamental principles so that they can be applied in varying situations, industry professionals experience engineering graduates who are unable to put into practice the fundamental principles that are memorized instead of being learned. Therein lies the discrepancy as demonstrated in Figure 8.

Path Forward:

Given that students are quite easily able to find solution manuals to textbooks on the internet, Engineering Educators face new challenges that did not exist even only five years ago. In response to this change, Educators have a number of alternatives:

1) Develop a new set of homework and exam problems each time the course is taught;
2) Use electronic question banks (online homework) that randomize problems so that each problem assigned to each student is unique;
3) Develop alternative assessment techniques, such as oral examinations or concept questions;
4) Request that publishers stop making solutions available via pdf and return to paper-based distribution - although, the availability of scanners with document feeders makes this approach somewhat flawed;
5) Business as usual – provide students with exam questions that are similar to assignment problems and then report strong, albeit superficial, learning outcomes.

None of these are optimal choices, but rather what is clear is that Educators need to do something to address the fact that student learning has been compromised by the availability of textbook solution manuals.

Continuing with the last alternative, the “business as usual approach” amounts to a pact between the Educator and the student, where both have agreed to follow the quick and easy approach of relying on the instructor’s manual that comes with the text for assessment rather than participating in more authentic forms of assessment. As Wiggins and McTighe (2006) note, authentic assessment is realistically contextualized, requires judgment and innovation, asks the student to “do” the subject, replicates key challenging situations, assesses the student’s ability to use a repertoire of knowledge and skills, and provides opportunities to rehearse and refine performance. From the Educator’s perspective, authentic assessments must be carefully designed; from the student’s perspective, they take time and effort to complete. As Educators, it is our role to not only ensure that our assessments are authentic, but also to help our students understand how they, themselves, contribute to their learning process. Achieving these types of assessments in a time-efficient manner is the challenge that lies before us.

CONCLUSIONS

This paper has examined the discrepancy between Industry Supervisors and Engineering Educators in terms of Mechanical Engineering graduates’ strengths in areas that include Technical Fundamentals, Interpersonal / Teamwork, Problem Solving and Critical Thinking, Design, Communication, and Experiments. Both observational and quantitative data was presented indicating that a strong reliance on textbook solution manuals has resulted in a scenario where students are able to perform relatively well on problems that mimic textbook questions, yet they can still lack an understanding of important concepts or fundamental topics. This phenomenon is most likely why Engineering Educators have been found to rate student performance higher than Industry Supervisors.

REFERENCES

Ambrose, S.A., Bridges, M.W. (2010). DiPietro, M., Lovett, M.C., Norman, M.K., How Learning Works, Seven Research-Based Principles for Smart Teaching, Jossey-Bass.

Cengel, Y., and Boles, M. (2011). Thermodynamics, An Engineering Approach, 7th Ed., McGraw Hill.

Crawley, E., Malmqvist, J., Ostlund, S., Brodeur, D. (2007). Rethinking Engineering Education – The CDIO Approach, Springer.

Kirkpatrick, A. T. and Danielson, S. (2012). “ASME Vision 2030’s Recommendations for Mechanical Engineering Education,” American Society of Engineering Education AC 2012-4805.

Mazur, E. (1997). Peer Instruction, A User’s Manual, Prentice Hall.

Perez-Pena, R. (2012). “Studies Find More Students Cheating, With High Achievers No Exception,” The New York Times, September 7.

Widmann, J. and Shollenberger, K. (2006). “Student Use of Textbook Solution Manuals: Student and Faculty Perspectives in a Large Mechanical Engineering Department,” American Society of Engineering Education 2006-756.

Wiggins, G. and McTighe, G. (2006). Understanding by Design. Expanded, 2nd Ed., Alexandria, VA: Association for Supervision and Curriculum Development.

Young, J. (2010). “High-Tech Cheating Abounds, and Professors Bear Some Blame,” The Chronicle of Higher Education, March 28.

BIOGRAPHICAL INFORMATION

Ronald J. Hugo is Professor of Mechanical and Manufacturing Engineering and Associate Dean (Teaching & Learning) at the University of Calgary. He is also the holder of the Engineering Education Innovation Chair in the Schulich School of Engineering. His research interests are in the areas of experimental fluid dynamics, energy systems, and engineering education.

Robert W. Brennan is Professor of Mechanical and Manufacturing Engineering and Associate Dean (Academic & Planning) at the Schulich School of Engineering. He has served on the steering committee of the Canadian Engineering Design Education Network (CDEN) and as chair of the Schulich School of Engineering’s Engineering Education Summit.

Corresponding author

Dr. Ron J Hugo
University of Calgary
2500 University Dr. NW
Calgary AB Canada T2N 1N4
hugo@ucalgary.ca