AC 2012-3181: COMPARING ENGINEERING STUDENT USE OF SOLUTION MANUALS AND STUDENT/FACULTY PERCEPTIONS OF ACADEMIC DISHONESTY

Ms. Angela L. Minichiello, Utah State University

Angela (Angie) Minichiello, Principal Lecturer in the Department of Engineering Education at Utah State University, instructs freshmen and sophomore engineering courses via distance education to students at the USU regional campuses. Minichiello is a registered professional Mechanical Engineer and has more than 15 years industry experience as a practicing engineer. She holds a B.S.M.E. degree from the U.S. Military Academy at West Point and a M.S.M.E. degree from the Georgia Institute of Technology. Her research interests include adult learning, cognition, and e-learning. She is a member of ASEE and ASME.

Dr. Laurie S. McNeill, Utah State University

Laurie McNeill is an Associate Professor in the Civil and Environmental Engineering Department at Utah State University.

Dr. Christine E. Hailey, Utah State University

Christine E. Hailey is Senior Associate Dean and professor of mechanical and aerospace engineering at Utah State University. She is the Principal Investigator and Director of the National Center for Engineering and Technology Education, an NSF-funded Center for Learning and Teaching. The NCETE is a collaborative network of scholars from nine institutions with backgrounds in technology education, engineering, and related fields. Its mission is to improve the understanding of the learning and teaching of high school students and teachers as they apply engineering design processes to technological problems. She is also the Principal Investigator of the Influence of MESA Activities on Underrepresented Students, a program funded by the DRK-12 program at NSF. This exploratory study examines the influences that those MESA activities have on students' perception of engineering and their self-efficacy and interest in engineering and their subsequent decisions to pursue careers in engineering.

Comparing Engineering Student Use of Solution Manuals and Student/Faculty Perceptions of Academic Dishonesty

Abstract

Since 2002, student access to engineering textbook solution manuals has dramatically increased due to the advent of their electronic availability.[1, 2] Newfound access to electronic solution manuals poses fresh ethical questions concerning when and how their use is considered "honest". Research[3] indicates that undergraduate engineering students agree that the instructor/ institution holds the primary responsibility for defining and limiting acts of academic dishonesty, not the student. Anecdotal evidence[1] suggests that faculty may perceive academic dishonesty in the use of solution manuals when students do not. This attitudinal mismatch can be a cause for misunderstanding and discord between and among engineering students and faculty that, ultimately, has a detrimental effect on student learning and assessment of teaching effectiveness.

This paper summarizes the results of a pilot study conducted within the College of Engineering (CoE) at a western, land-grant, state university to extend the original work conducted at California Polytechnic State University (Cal Poly), San Luis Obispo (SLO). In 2006, Cal Poly SLO researchers reported student and faculty perceptions of the ethics of student use of textbook solution manuals, as measured by direct question surveys of engineering faculty and students, differed significantly.[1] In 2007, researchers reported that levels of engineering student academic achievements, as measured by homework and exam scores, were higher when students did not have access to solution manuals during homework preparation.[2]

Replicating previous work, the current study uses direct survey of engineering undergraduates and faculty engaged in teaching undergraduate engineering courses to assess differences in the perceptions of academic honesty related to student use of solution manuals. Student participants are enrolled in one of two sophomore-level engineering mechanics courses (Statics and Dynamics) or a junior level environmental engineering course (Environmental Management). As in the previous Cal Poly SLO studies,[1,2] courses involved in the current study make use of assigned homework as the primary mechanism of problem solving practice.

The results of the current study are important in helping to 1) clarify the nature of the attitudinal mismatch between engineering students and faculty concerning the use of solution manuals, 2) develop means to promote acceptable learning-based uses for online and electronic textbook solution manuals, and 3) extend the body of knowledge concerning engineering student and faculty perceptions of academic integrity.

Introduction

It is widely held that the topic of academic integrity is a current issue of critical importance for higher education due to the frequency of dishonest acts (i.e. "cheating") committed by students.[4] Incidents of academic dishonesty have potentially far-reaching implications for teaching and learning. From a list of possible implications posed by acts of academic dishonesty discussed by Passow, Mayhew, Finelli, Harding and Carpenter[5], those that we believe hold particular interest for engineering education include:

- Increasing likelihood for dishonest behavior of students as engineering professionals, researchers, or graduate students
- Nullifying common measures used to assess student learning and teaching effectiveness
- Undermining new instructional emphasis being placed on the topic of engineering ethics which is now required for engineering accreditation.

It is interesting to point out that, as Passow et al.[5] also note, while the prevalence of acts of academic dishonesty of engineering students is self-reported at the second highest level (74%) among undergraduate disciplines including business, science, and the humanities,[6] there remains a disparate gap in the educational literature concerning the study of academic dishonesty among them. Passow et al.[5] report that, other than their own study, there have been few previous and only three *multi-institutional* studies[7, 8, 9] documented in the educational literature that differentiate cheating behaviors among engineering students from that of other disciplines. It is important to the perceived relevance of the current study to note that all of the multi-institutional studies were conducted prior to the extensive availability of online textbook solutions manuals.

Background

Historically, students and teachers have had different views concerning behavior considered to be dishonest or labeled as "cheating". [3,4] The advent of easy electronic access to information that, as little as a decade ago, was generally unavailable to students brings new uncertainty to the types of student behavior that may be considered honest. Some behaviors, such as those dubbed "echeating" in a recent USA Today news article- texting answers to exam questions or covertly "phoning a friend" during an exam with the use of tiny, wireless ear buds- are unquestionably dishonest .[10] Other behaviors that also take advantage of our expanding capability to access data electronically, however, may not be as clear-cut. For example, in 2011 one in three students admitted to using the internet to plagiarize an assignment and only 29% of students (down from 34% a decade ago) believe that copying from the internet is "serious" cheating.[11] As it would appear, the lines between right and wrong appear less distinct when viewed online from an LCD screen.

Interestingly, in surveying 643 engineering and pre-engineering undergraduates at eleven institutions throughout the US and abroad, Carpenter et al.[3] found that today's engineering undergraduates strongly place the burden of responsibility to prevent acts of academic dishonesty on the instructor (79.3% agree or strongly agree) or the institution (72.5% agree or strongly agree) instead of on themselves (21.6% agree or strongly agree). Furthermore, while a majority of respondents (59.6%) agreed that non-reporting of academic dishonesty was itself an unethical act, most students in this survey did not disagree with the statement that they would do nothing if they witnessed an act of cheating. Thus, this study illuminates the necessity for faculty and administration to take a lead in understanding the learning environment and clearly communicating student behavioral expectations in order to limit or reduce academic dishonesty.

Due to faculty perceptions of increasing accessibility to and use of textbook solution manuals by engineering students at Cal Poly SLO, a large, western state, public engineering school, Widmann and Shollenberger [1] administered two self-developed direct question surveys to engineering students and faculty. The first was administered to 674 engineering undergraduates

and the second to 13 mechanical engineering faculty at the school. The goal of the surveys was to assess the frequency of use of solution manuals by students to complete required homework sets and to determine variations in student and faculty perceptions of the honesty and educational usefulness of this practice. The surveys were part of a larger study conducted to determine the effects of student use of solution manuals on their learning.[2]

The key findings of the preliminary study by Widmann & Shollenberger[1] are:

- Eight out of ten courses surveyed had textbook solution manuals available in electronic form.
- Nine out of ten of students reported having used textbook solution manuals not distributed by instructors to help with assigned homework or as a study aid at Cal Ploy SLO.
- Student use of solution manuals is widespread (75%) in courses where solution manuals are available electronically compared to courses where solution manuals are available in bound form only (9%).
- Engineering students were commonly unaware that approximately 1/3 of faculty specifically forbade the use of solutions manuals in their courses.
- Most faculty (77%) consider use of solution manuals in completing homework assignments a form of cheating while most students (84%) do not.
- While the overall frequency of engineering student solution manual use is high (most students have used them at least once), it is not as high as perceived by the faculty.

In the current work, the authors replicate the work of Widmann and Shollenberger [1] within the College of Engineering of a large, western state, public land grant university. This research is motivated by anecdotal evidence at this university that engineering students use - and possibly misuse - textbook solution manuals: students hand in homework assignments with errors that appear to be directly copied from errors in the solution manual, students score high on homework sets but low on exams that are based largely on homework problems, and students cannot orally explain their written homework solutions ("I don't know how I got that...").

This research is further motivated by the critical importance of replication in advancing research in education. Replication of educational studies, using comparable methods, participants and conditions, is essential for the purposes of generalizing findings to broader populations and settings than are typically represented in a single study.[12-15]

Research Questions

The research questions that were used to guide this preliminary research study are:

1. How widespread is textbook solution manual availability and in what form(s)?
2. How widespread is engineering student use of textbook solution manuals and for what purpose(s)?
3. How do perceptions of academic dishonesty differ between engineering students and faculty concerning the use of textbook solutions manuals?

We anticipated that student reports of electronic solution manual accessibility, solution manual usage, and differences in attitudes between students and faculty to be similar to and possibly more pronounced than those found at Cal Poly SLO. This expectation is mainly due to larger engineering class sizes and resultant larger engineering student to faculty ratios at our university. While Cal Poly SLO class sizes were held at or below 35 students, our introductory engineering courses can exceed 100 students.

Description of the Surveys Instruments

Overall, our goal was to replicate the work of Widmann and Shollenberger[1] at our university as closely as possible. Therefore, we attempted to keep student and faculty surveys as close to their original form as possible.

Student Survey. We used the student survey instrument survey developed by Widmann and Shollenberger [1] with some minor modifications. Original student survey questions are divided into two sections: Background information (Questions #1-11) and Course specific topics (Questions #12-20). The background information section can be further divided into questions concerning student demographic information (#1-6) and questions concerning student attitudes about the value of homework and use of solutions manuals in general (#7-11). Course specific questions (#12-20) pertain to course policies regarding homework and use of solutions manuals for the particular course being surveyed.

Modifications to the original Cal Poly student survey instrument were limited to the name change of the institution and the types of engineering majors available. Additionally, question #21 was added to investigate student motivations for using solution manuals:

Please circle all of the statements that apply to your use of textbook solution manuals.

- I only use a solution manual to check my answer to a homework problem.
- I use a solution manual after I've tried to solve an assigned problem on my own.
- I work extra problems that are not assigned and use the solution manual to check my solution.
- I often copy the entire solution from the solution manual to help me manage my time.
- I often copy the entire solution from the solution manual because the instructor did not adequately cover the material required to solve the problem.
- I never use a solution manual.

Finally, in order to insure student anonymity, we administered the student survey in a pencil and paper format. The original student survey was administered online via the course management system.

Faculty Survey. We used the faculty survey instrument survey developed by Widmann and Shollenberger [1] with some minor modifications. The original survey asked faculty to provide limited demographic information, information concerning their use of homework assignments as pedagogical tools, and their attitudes and policies related to grading homework and use of solution manuals *for the specific course in which the students were being surveyed*.

Modifications of the original Cal Poly SLO faculty survey included changing the name of the institution and the types of faculty positions responses available. Additionally, question #9 on the Cal Poly SLO survey (related to class GPA) was deleted. Question #15 was added to investigate faculty perceptions of student motivations for using solution manuals:

> Please circle the single best statement that describes student use of solution manuals in your undergraduate course.
>
> a) Students only use solution manuals to check their answer to a homework problem.
> b) Students only use a solution manual after they have tried to solve an assigned problem on their own.
> c) Students work extra problems that are not assigned and use the solution manual to check their solutions.
> d) Students often copy the entire solution from the solution manual to help with time management.
> e) Students often copy the entire solution from the solution manual because they are not willing to read the textbook, review their notes, and try to solve the problem on their own.
> f) Students never use solution manuals in my class.

We constructed and administered an online version of the faculty survey in an effort to reach all faculty members in the College of Engineering, rather than just those responsible for teaching the courses being surveyed. Surveying only faculty teaching the courses in which we surveyed students would have tremendously limited our faculty sample size. During the online survey, faculty could elect to respond and answer only basic questions (#1 - 6). Instructors not teaching any undergraduate course were exited out of the survey prior to reaching course-specific questions (#7 - 15). Faculty members currently teaching an undergraduate course, however, were asked to complete the entire survey.

Google Docs was used as the online platform for administering the survey. In order to keep the online survey truly anonymous, however, we did not place controls (IP address tracking, ID number tracking, etc.) on the survey to limit faculty from replying more once. We considered the risk of faculty replying multiple times to be very minimal and agreed that the need for complete anonymity outweighed this risk.

We note that both the original survey instruments and our modified instruments are available for use at other institutions for those interested in extending the generalizable results of these studies.

Research Methodology

Student Survey. Sometime after the midpoint of the Fall 2011 semester, students in two sophomore undergraduate mechanics courses (ENGR 2010 Statics and ENGR 2030 Dynamics) and one junior level civil engineering course (CEE 3610 Environmental Management) were met with by one of the faculty researchers for approximately 15-20 minutes during a regular class period to introduce the research study and discuss the Internal Review Board (IRB) Letter of

Information (LOI). Students were provided a hard copy LOI and asked to consider completing an anonymous, pencil and paper copy of the student survey when the researcher returned to the class during the last two weeks of class. Researchers explained the motivation for completing the survey and that the survey would be completely anonymous. During a second meeting that occurred sometime during the last two weeks of the course, students were given 10-15 minutes during class to complete the pencil and paper survey. Care was taken to insure that the researcher that introduced the LOI and administered the survey was not the instructor of the course being surveyed. In all but one case, the instructor teaching the course was not in the room during these meetings. Distance sections of ENGR 2010 were included in the survey; a researcher met with distance ENGR 2010 students over the distance education video broadcast system to introduce and to administer the survey.

Faculty Survey. In November 2011, 87 of the 95 faculty in the College of Engineering were sent an email introducing the study and providing a link to the online survey, which included the LOI. (Faculty not included in the email were not on the distribution list because they were either on sabbatical or inadvertently left off.) The email explained the motivation for the research study and that the survey would be completely anonymous. The survey was open for a period of two weeks, and a reminder email was sent one week after the initial email.

Demographics of the Sample

Institution. Utah State University (USU) is one of the nation's premier student-centered land grant and space grant universities. We foster the principle that academics come first; we cultivate diversity of thought and culture; and we serve the public through learning, discovery, and engagement. Our total university enrollment in 2011 was 28,994 students.

The USU College of Engineering houses seven ABET accredited undergraduate degrees in Biological, Civil, Computer, Electrical, Environmental and Mechanical Engineering and Computer Science. A newly developed associates degree program in pre-engineering is offered at four regional campuses. USU awarded 156 undergraduate engineering degrees in 2011. Our Fall 2011 undergraduate engineering enrollment was 1569 students on the main campus. The College of Engineering is composed of 91 faculty members on the main campus and at four regional campuses.

Respondents.

Student Respondents. The total enrollment in the courses surveyed was 269 students. Our student survey had 195 engineering student respondents. The difference in total enrollment and number of responses indicates that a number of students were not in class to take the survey or elected not to complete the survey. Since there are approximately 1569 engineering students in the CoE, the student survey was completed by approximately 12.4% of this population. This percentage is similar to the student response rate at Cal Poly SLO (14.6%)[1]

Of the student respondents, 166 (86%) of respondents were male. This sample is representative of the 2011 civil/environmental/mechanical engineering student population at our institution (89.6% male). Seventy-eight (40%) of the respondents reported as civil and environmental

engineering majors, 92 (48%) reported as mechanical and aerospace engineering majors, and 16 (8%) reported as biological engineering majors. The remaining 4% of students self- reported as electrical and computer engineering majors (1), other engineering majors (1), non-engineering majors (3), or did not report a major (3). Of those students surveyed, 13% are under the age of 20, 66% are between 20-24 years of age, 18% are between 25-30 years of age, and 1.5% are above 30 years of age. Students surveyed included 1.6% freshmen, 48% sophomores, 39% juniors, 6% seniors, and 6% above 4-year seniors.

A comparison of the characteristics of the current engineering student sample with the Cal Poly SLO student sample is provided in Table 1. In general, the Cal Poly SLO sample of engineering students is predominantly mechanical engineering majors where the current sample is balanced between civil/environmental and mechanical engineering majors. Additionally, the Cal Poly SLO sample consists of younger students who, although they are younger, have been in school longer.

Table 1. Sample Comparison: Current study vs. Cal Poly SLO[1]

Student Sample Characteristic		% of current sample	% of Cal Poly SLO sample
Discipline	Civil/Environmental	40.7	15.6
	Mechanical	47.9*	67.4
	Aerospace		6.2
	Other Engineering	9.0**	10.2
Class Level	Freshman	1.6	0.2
	Sophomore	47.9	20.5
	Junior	39.1	33.1
	Senior	5.7	28.3
	> 4 year	5.7	17.9
Age	Under 20	13.0	19.4
	20-24	66.2	75.0
	25-30	18.8	3.6
	> 30	1.6	2.0
Admitted as Freshmen		68.9	76.3

* Mechanical and aerospace engineering combined total
** Includes those reporting as biological, electrical and computing, and "other" engineering

Widmann and Shollenberger[1] report that the student age breakdown of their sample is representative of the "traditional age" student body at Cal poly SLO. The current sample, however, has smaller representation in the traditional age groups (under 20, 20-24) and greater representation of the non-traditional age group (25-30). These trends are in line with our predominantly non-traditional student population: many (if not most) of our students complete a two-year religious training prior to completing their degrees.

Class years represented in the current sample (47.9% sophomore, 39.1% junior) were representative for the courses surveyed (two sophomore level courses Statics and Dynamics, one junior level course Environmental Management). Comparatively, Widmann and Shollenberger[1] surveyed three sophomore level courses, three junior level courses, and two senior level courses.

Therefore, the Cal Poly SLO sample is marked by larger a representation of senior and >4 year students which, Widmann and Shollenberger note, is commensurate with the typical 5 year graduation rate at Cal Poly SLO.

Faculty Respondents. Thirty-eight faculty members filled out the online faculty survey, representing a response rate of 44%. Response rates for each category of faculty position are shown in Table 2. Of the 38 faculty responding, 25 (66%) were currently teaching an undergraduate class, and thus filled out the entire survey. The 13 faculty members who were not teaching an undergraduate class exited the survey after question #6 and did not answer the course-specific questions.

Table 2. Faculty Survey Response Details

Faculty Category	Number Responding	Response Rate
Assistant Professor	10	59%
Associate Professor	14	54%
Professor	4	24%
Lecturer	4	40%
Research Professor	2	29%
Administrator	4	40%

Limitations. Because we directed our faculty survey to all engineering faculty teaching an undergraduate engineering course during the semester, our faculty results are not directly comparable to the faculty results of the Cal Poly SLO study. General conclusions concerning faculty perceptions of solution manual prevalence and use should be comparable, however.

The questions we added to the two surveys (#21 on the student survey and #15 on the faculty survey) are not directly comparable to each other since #21 on the student survey asked student to pick all responses that apply and #15 on the faculty survey asked faculty to choose the one best response.

Results and Discussion

Assigned Homework Problems and Problem Solutions. Similar to the study of Widmann and Shollenberger[1], three survey questions were asked, on each survey, to determine the degree to which students and faculty feel that assigned homework problems and solutions aid learning. Results from these questions are shown in Table 3.

In general, students (94% agree) and faculty (95% agree) at our institution are in agreement that turning in homework problems to be graded contributes to learning. This result aligns with the Cal Poly study that showed that 89% students were in one of the three "agree" categories and 100% of Cal Poly faculty were in the 'strongly agree' or 'somewhat agree' categories.[1] There was a discernable difference between students and faculty, however, in perceived usefulness of any solutions to textbook problems (general question) and the solution manual for the specific class; students found them very useful, while faculty did not. This is very similar to the trend reported in the Cal Poly study[1].

Table 3. Perceived Usefulness of Assigned Homework Problems and Solutions

	Strongly agree	Somewhat agree	Agree	Somewhat disagree	Strongly Disagree
General Survey Questions					
Student: Turning in assigned homework problems to be graded contributes significantly to your understanding of a subject.	**61%**	22%	11%	5%	1%
Faculty: Turning in assigned homework problems to be graded contributes significantly to your students' understanding of a subject.	**45%**	21%	29%	5%	0%
Student: Any solutions to textbook problems (other than the example problems included in the text) are a useful study guide.	**68%**	19%	12%	2%	0%
Faculty: Any solutions to textbook problems (other than the example problems included in the text) are a useful study guide for students.	3%	32%	**40%**	21%	5%
Course Specific Questions					
Student: Do you generally find the solution manual a useful study guide?	**50%**	29%	12%	8%	1%
Faculty: Textbook solution manuals are a useful study guide for students.	0%	20%	**28%**	**28%**	24%

Therefore, our results support original findings that 1) student and faculty agree that preparing homework problems improves student learning and 2) students agree but faculty disagree that solution manuals are a useful tool in preparing homework and studying. Understanding the reasons behind this difference in the perceived benefit of solution manual use is an important area to study in future work.

Forbidden Use of Solution Manuals and Perceptions of Cheating. Survey data from our institution shows that 40% of faculty report that they have forbidden use of solution manuals in their undergraduate courses, while only 11% of students say that solution manual use has been forbidden in the specific undergraduate course being surveyed. While this difference between faculty and student response supports similar findings at Cal Poly SLO, we caution that care should be used when interpreting this result since the courses for which our faculty are responding are not, necessarily, the same courses for which our students are responding.

Survey data from our institution also show a marked difference between student and faculty perceptions as to whether use of a solution manual is considered "cheating". The difference is apparent in both the general and course specific questions shown in Table 4.

Table 4. Perceptions of Cheating

	Strongly agree	Somewhat agree	Agree	Somewhat disagree	Strongly Disagree
General Survey Questions					
Student: The use of a textbook solution manual, not distributed by the professor, as an aid to solving assigned homework problems is cheating.	1%	6%	5%	44%	**45%**
Faculty: The use of a textbook solution manual, not distributed by the professor, as an aid to solving assigned homework problems is cheating.	11%	29%	**37%**	21%	3%
Course Specific Questions					
Student: For this course, the use of a textbook solution manual, not distributed by the professor, as an aid to solving assigned homework problems is cheating.	6%	4%	3%	40%	**46%**
Faculty: For this course, the use of a textbook solution manual, not distributed by the professor, as an aid to solving assigned homework problems is cheating.	24%	12%	16%	**28%**	20%

Our students, in general, do not believe it is cheating (89% disagree) to use a solution manual, not distributed by the professor, as an aid in solving assigned homework problems. This result is in line with the results of the Cal Poly study (84% disagree). [1] For the students, this result was the similar for both the general and course specific question. Again, this result supports the findings of the Cal Poly study.[1]

Faculty responses to the general question show agreement that use of textbook solution manuals, not distributed by the professor, is cheating (77% agree). This result again is very close to the Cal Poly result (77% agree).[1] Faculty responses are mixed for the course specific question in our survey. It is important to note that for the course specific questions, no direct correlation can be made between student and faculty responses because the faculty survey was opened up to allow faculty teaching any undergraduate engineering course (not necessarily one of the courses being surveyed) to respond.

Our results support the findings of Widmann and Shollenberger[1] that faculty perceive that use of a textbook solution manual is cheating when students do not. Understanding and developing strategies to reduce this difference in perception is an important focus for future work.

Student Use of Textbook Solution Manuals. The majority of our students always (6%), usually (34%), or occasionally (42%) use textbook solution manuals, not distributed by the professor, to help with assigned homework or as a study aid as shown in Table 5. Only 5% of our students have never used a solution manual. This result is in keeping with the 2006 results of Widmann and Shollenberger [1] (10% of Cal Poly SLO engineering students reported never having

used solution manuals) and supports a claim that solution manual use among undergraduate engineering students has remained constant or increased over the last five years.

Table 5. Student Use and Faculty Perceptions of Student Use of Solution Manuals

	Always	Usually	Occasionally	Rarely	Never
General Survey Questions					
Student: Have you used textbook solution manuals not distributed by the professor for courses at the University to either help with assigned homework or as a study aid?	6%	34%	**42%**	13%	5%
Faculty: How often do you think that students have used textbook solution manuals to either help with assigned homework or as a study aid for any course you have taught?	0%	**42%**	**42%**	16%	0%
Course Specific Questions					
Student: Have you used the solution manual as an aid to solving assigned homework problems?	13%	29%	**37%**	19%	2%
Faculty: In your experience, if students use textbook solution manuals, how often do they use them as an aid to solving assigned homework problems?	12%	**40%**	28%	4%	16%
Student: Have you used the solution manual as a study guide in preparation for a quiz or exam?	20%	24%	**32%**	12%	11%
Faculty: In your experience, if students use textbook solution manuals, do they use them as a study guide in preparation for a quiz or exam?	8%	**36%**	28%	20%	8%

Our faculty's perception of student use of solution manuals is in line with student self-reporting of their use. This result is a difference from the original study conducted at Cal Poly SLO where researchers found that faculty tended to overestimate student usage of solutions manuals.

Therefore, our results support original findings that most undergraduate engineering students use solution manuals, not distributed by the professor, as a homework preparation and study aid. Our results conflict with original findings that faculty overestimate student solution manual use.

Availability of Solution Manuals. One perplexing result is that, despite students reporting widespread use of solution manuals to solve homework problems and study in specific courses surveyed (Table 5), when asked if they had access to the solution manual for the specific class, 44% of the students responded "no". One explanation may be that one of the courses surveyed, CEE 3610 Environmental Management, did not use textbook based homework and therefore there were no solution manuals available for that course.

Fifty-two percent of students reported having access to the electronic version of the solutions, 3% had the bound version, and 0.5% each had access to both bound and electronic versions, or copies of solutions from former students. This result is consistent with the Cal Poly results: students with access to solution manuals overwhelmingly had access to the electronic version. Access was from a friend or colleague (66%), found on the internet (21%), purchased on the internet (6%), or purchased at a store (1%).

Widespread electronic availability is confirmed by the faculty responses to the course-specific survey questions: 44% of solution manuals are available electronically only, 40% are available in both electronically and bound form, and 16% are available in bound form only. *Therefore our results support original findings that solution manuals are widely available in electronic form.*

Motivation for using solution manuals. Two questions were added to the original surveys to investigate student motivation for and faculty perceptions of solution manual use (Table 6). Although student and faculty response rates cannot be directly compared because the choices differed between the two surveys, the data suggests a difference in reported (student) and perceived (faculty) reasons for use. The most common faculty responses were that students copy solutions because they are not willing to do the work on their own (36%) and that students only use the manual after they've tried the problem on their own (32%). In contrast, 89% of students report using the manual after they tried the problem on their own, and 51% only use the manual to check a final answer. A minority of students report copying the entire solution, either because the instructor failed to adequately cover the material (9%) or to help manage time (10%).

Table 6. Motivation for Using Solution Manuals

Student question #21 and response rate (choosing all that apply)		**Faculty** question # 15 and response rate (choosing only one)	
I only use a solution manual to check my answer to a homework problem	51%	Students only use solution manuals to check their answer to a homework problem	0%
I use a solution manual after I've tried to solve an assigned problem on my own	**89%**	Students only use a solution manual after they have tried to solve an assigned problem on their own	32%
I work extra problems that are not assigned and use the solution manual to check my solution	44%	Students work extra problems that are not assigned and use the solution manual to check their solutions	8%
I often copy the entire solution from the solution manual to help me manage my time	10%	Students often copy the entire solution from the solution manual to help with time management	12%
I often copy the entire solution from the solution manual because the instructor did not adequately cover the material required to solve the problem	9%	Students often copy the entire solution from the solution manual because they are not willing to read the textbook, review their notes, and try to solve the problem on their own	**36%**
I never use a solution manual	3%	Students never use solution manuals in my class	12%

To further investigate the motivation for student use of textbook solution manuals, we analyzed data to determine possible relationships between students' self-reported GPA and their use of solution manuals and homework problems. Specifically, we calculated sample Pearson correlation coefficients between students' self-reported current GPA (student survey question #5) and the following student survey questions:

#8. Have you used textbook solution manuals not distributed by the professor for courses at [our institution] to either help with assigned homework or as a study aid?
#9. Turning in assigned homework problems to be graded contributes significantly to your understanding of a subject.
#10. Any solutions to textbook problems (other than the example problems included in the text) are a useful study guide.
#11. The use of a textbook solution manual, not distributed by the professor, as an aid to solving assigned homework problems is cheating.

The correlation coefficients were: calculated to be: -0.03 (#5 and #8), -0.03 (#5 and #9), 0.16 (#5 and #10), and -0.05 (#5 and #11). The results suggest that there is no significant relationship between a student's cumulative GPA and his or her response to items 8 through 11. The results support previous statements that solution manual use is widespread; students with high GPAs are as likely to use solution manuals as a study aid as students with low GPAs. Furthermore, student perceptions concerning the ethics of solution manual use is consistent across GPA levels; students with high GPAs are as likely to view using solution manuals as cheating as students with low GPAs.

Conclusions

This study of solution manual use by engineering students in a western, land grant, state university provides insights toward understanding our research questions:

1. **How widespread is textbook solution manual availability and in what form(s)?**

   Textbook solution manuals are widely availability to students, predominantly in electronic form. Eighty-seven percent of students got the manual either from a friend/colleague or on the internet, while only 7% purchased the manual.

2. **How widespread is engineering student use of textbook solution manuals and for what purpose(s)?**

   Nearly all students report using a solution manual at some point; only 5% claim to never have used one. Solution manual use is not limited to or correlated to student cumulative GPA. Students commonly use the solution manual to help with homework and study for quizzes/exams. Most students report using the manual only to check final answers or after they have tried the problem on their own; very few report directly copying solutions.

3. **How do perceptions of academic dishonesty differ between engineering students and faculty concerning the use of textbook solutions manuals?**

There is a very large mismatch between student and faculty perceptions of academic dishonesty with regards to use of solution manuals. Only 11% of students, compared with 77% of faculty, perceive this as cheating.

Overall, our results support the claim that undergraduate engineering student use of textbook solution manuals is both widespread and commonly practiced among this population, despite faculty concerns that solution manual use maybe unethical or an impediment to student learning. It is also not clear the extent to which students are truly aware of or understand faculty concerns. Students do not appear to place the heightened sense of ethical implication on the use of solution manuals that faculty do; perhaps this is because solution manuals are most often accessed electronically and students are unaware of or complacent in regards to legal (copyright) and ethical (plagarism) implications as they relate to electronic or online information.
Proposed future work would investigate student understanding of legal and ethical implications of the use of electronic information in order to determine if faculty concerns are warranted.

Implications for Engineering Education

The results of the current study, especially when viewed in context of their support of similar findings obtained at Cal Poly SLO 5-6 years ago, bear important implications for undergraduate engineering education. Clearly, student access to electronic data, including textbook solution manuals, is not subsiding. Neither is the internet savvy of our engineering students. A critical skill in today's professional environment, this proclivity to rapidly access information via the internet is, instead, blossoming and will most likely continue to grow with future generations of students.

Very broadly, our results indicate pervasive and conflicting perceptions between engineering students and engineering faculty in the following areas:

- Course policy concerning solutions manual use.
- Ethics concerning the appropriate use of online solution manuals.
- Benefits of worked out problem solutions, as found in solutions manuals, to student learning.
- Students' metacognitive abilities to assess, monitor and regulate their solution manuals use.

These key areas of dissonance between students and faculty are the areas to be targeted with proposed solutions to the solution manual problem in engineering education.

Course policy concerning solution manual use. Our results indicate that a pervasive culture among engineering students exists in which information, including solutions manuals, accessed online is so-called "fair game". This culture appears to persist even in courses in which instructors aggressively employ commonly accepted instructional strategies (syllabi, in class announcements, reading the institutional honor code in class) to indicate that use of textbook solutions manuals is forbidden.

One explanation of this phenomenon could be the fact that young people today grow up accessing the internet and using information contained there with little requirement to understand or acknowledge who owns this information. To youth, online information is akin to "free-money". Thus, instructor calls to eschew certain sources of online information may not resonate with today's students. This problem is most certainly exacerbated within institutions in which engineering faculty enact course policies that significantly differ on this issue.

Our findings point to the need for engineering department and/or college level support to faculty in helping to modify these student cultural norms. While there is no single best solution for all institutions, engineering faculty should agree on a common stance concerning solution manual use within their department or college. This stance must be clearly communicated to students not only by individual faculty through their course requirements, but also by departmental policies that include the specific actions to be taken in the event of non-compliance. Only with department (or higher) level support will individual faculty be able to effectively employ course requirements concerning solutions manuals.

Ethics concerning the appropriate use online solution manuals. Our results indicate that, in general, engineering students may not understand or have internalized standards for ethical and legal use of online information. Ethics training concerning the proper use of information in writing, as is traditionally taught in English courses, may not, for many students, map analogously to engineering courses focusing on mathematical problem solving as opposed to written reasoning.

Our findings suggest that instruction concerning the ethical use of information, most notably online information, *within an engineering context* is a critical component of undergraduate engineering curricula. One idea to explore may be the incorporation of online information ethics instruction within a larger ethics segment required as part of an introductory freshman experience. This training would lay a foundation for the understanding of ethical responsibility and professional practice as required by ABET Criterion 3f.[16] This foundation could be strengthened with supporting ethics instruction in follow-on years.

Benefits of problem solutions to student learning. Self-report responses show that undergraduate engineering students perceive that worked out problem solutions benefit their learning of problem solving skills. This is an important result that should not be overlooked, especially as the U.S. aggressively seeks new ways to improve student learning outcomes in science, technology, engineering and mathematics (STEM). Research literature concerning metacognition in science education[17] points to the use of a specific learning strategy called *self-explanations*. Self-explanations used by students during the study of worked out problem solutions are shown to improve learning outcomes for problem solving objectives. While the self-explanations researched in this study were *spontaneous,* later research[18] indicated that instructors can purposefully elicit self-explanations from students as means of teaching these important problem solving strategies. Our findings suggest that teaching such methods to students can enhance undergraduate engineering instruction. If students are prepared to employ proven learning strategies using worked out problems, the instance of misuse and direct copying of solutions may be reduced.

Students' metacognitive abilities to regulate their solution manual use. Despite student's belief that worked out problem solutions benefit their learning, the level to which engineering undergraduates can regulate their own cognitive activities during learning remains an open question. Clearly these *metacognitive* activities, which include monitoring, assessing and regulating one's learning activities, can themselves be learned.[17,18] Not all students, however, begin undergraduate engineering programs with the same level of metacognitive skills. For some, the pressures (e.g. workload, time constraints, grades, etc) of a typical undergraduate engineering program may usurp weak metacognitive skills and result in unproductive or unethical use of solution manuals even though original cognitive intentions were noble.

Therefore, as educators we must consider alternate means to provide graded assignments in undergraduate engineering courses. Reliance on traditional, heavily weighted homework assignments based on textbook problems may provide too great a temptation for many students to resist. Thus, traditional textbook homework assignments may no longer be "best practice" in light of student ease of access to online solution manuals. Options for more productive assignment frameworks may include but are not limited to: instructor created homework problems to which online (or other) solutions are not available, procedural homework problems in which the solution process instead of the equation and/or numerical analysis is required, and individual or peer critique of homework for credit. As illustration, anecdotal evidence from a student comment on a Fall 2011 end of course evaluation for CEE 3610 Environmental Management supports this idea:

> **Q:** "What aspects of this course did you feel were especially good?"
>
> **A:** "Not having homework problems straight out of the book (forced me to do my own work instead of copying the solution manual)."

Moreover, increasingly textbook publishers are providing online homework systems and adaptive problem databases that can be used to create individualized homework sets that are, in many cases, graded electronically. These homework systems have potential for providing individualized homework sets that provide quick student feedback without requiring a herculean effort on the part of the instructor. Faculty would do well to maintain pressure on textbook publishers to provide efficient and effective homework systems or problem databases so as to lessen reliance on traditional solution manuals.

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