AC 2011-1521: COMPARISON OF INSTRUCTOR PERCEPTIONS AND STUDENT REFLECTIONS ON MODEL ELICITING ACTIVITIES

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Comparison of Instructor Perceptions and Student Reflections on Model Eliciting Activities

Introduction

Instructors can impact student learning through their expectations of student achievement[1-6]. We examine how faculty perceptions of concepts learned and skills gained compare to that of students to better understand this premise. Specifically, to investigate this issue, an educational intervention, model eliciting activity (MEA), was implemented in four engineering courses. MEAs present complex, realistic, open-ended problems to students to reinforce targeted concepts. Assessment of student understanding was measured through student teams' written responses to the MEAs, pre-post concept inventories, as well as a comprehensive reflection tool. That reflection tool (RT) serves as both an assessment instrument and educational intervention that provides an opportunity for students to articulate what they have learned and thus helps instructors gain insight into their team performance and the problem solving processes. Our RT questions are in four categories: teamwork, problem solving, professional skills and technical concepts learned. Through the analysis of the reflection surveys coupled with interviews with the faculty implementing the MEAs we address the following questions: What are the instructors' expectations of what students learn or gain from an MEA? And, how does this compare to what students actually report that they have learned or gained from the MEA?

This paper reports on the use of MEAs and accompanying reflection survey designed to help student understanding of targeted concepts. It addresses the question, "to what extant are instructors aware of what their students have learned from a problem solving experience?" In particular, it focuses on the use of MEAs within four courses - Biotransport Phenomena, Probability and Statistics for Engineers 1, Transport Phenomena and Engineering Economic Analysis. For each course, the instructors were interviewed upon completion of the particular MEAs employed in their course using an interview protocol adapted from the students' RT. The students' reflection responses and performance were then compared with instructors' perceptions and expectations. This paper explores the similarities and differences between instructor and students regarding technical concepts and professional skills and investigates potential patterns across the different student cohorts.

Background

Instructors want their students to learn and be successful upon graduating. Learning outcomes are being increasingly investigated, as well as methods to help improve student achievement. The role of the instructor in a classroom is very important; both what the instructor teaches, and the instructor's expectations for their students ultimately impacts student performance. Clearly, the instructor is the single largest, inside the classroom factor, influencing student achievement[1]. In a related study, Sanders and Horn's[2] statistical examination of a large database of students, their outcomes, schools and their instructors, observed that "teacher effects on student achievement have been found to be both additive and cumulative". In addition to the teacher effects, the teacher expectations can also impact student performance[3]. Over 40 years ago Rosenthal and Jacobson showed that if instructors had higher expectations of students, those students did perform better, (i.e., the Pygmalion effect)[4]. More recent studies have revisited and further investigated those initial findings, citing other influential factors such as student perceptions, social perception and self-fulfilling prophecies[5,6].

Model Eliciting Activities (MEAs) are realistic, open ended problems that students solve in teams[7-9]. We have extended the MEA methodology by introducing an ethical dilemma that students also must consider in the problem situation[10]. The solutions student teams complete are in memo format and require generalizable procedures, which help reveal their thought processes (including assumptions, decisions made about the problem and solution strategies)[9]. Other studies have investigated the impact of MEAs on conceptual learning and the instructors' perspectives, including a paper in these proceedings which observed the improvement of student attainment of ABET outcomes using MEAs[11-13].

MEAs can address a combination of technical and professional skills, which makes it more challenging to assess the student learning. One method is to use a Reflection Tool (RT) - a survey like instrument that guides the student's reflection process through open ended and closed questions. The RT assists the student in the application of reflection as a guided activity. Hence, a reflection tool can help students articulate what they have learned and help instructors gain insight into team performance. When combined with engineering problem solving, the RT provides a combined process of analysis and self-evaulation[14]. Here the RT covers three categories each focused on different aspects: process, problem solving and targeted concepts learned (both engineering concepts from the course and professional skills)[14-16]. The RT that we are currently using is the third generation[15]. The RT has been refined to better guide students' reflective thinking by providing definitions of key terms and aligning them with both the course's main technical concepts and certain ABET professional skills. (To view the different versions of the RT, please see http://modelsandmodeling.net/Home.html.)

Methodology

Instructors and Courses

Taking the importance of the role of the instructor into consideration, four engineering faculty members who used non-conventional teaching interventions (MEAs and RTs) were interviewed. The four courses were offered in the Fall 2009 semester: Engineering Economic Analysis (Instructor 1), Probability and Statistics for Engineers 1 (Instructor 2), Biotransport Phenomena (Instructor 3) and Transport Phenomena (Instructor 4). The first three were taught at the same university and the fourth class at a different university. The first university is a medium sized public university. The second is a small public university focused on engineering and the sciences. The Engineering Economic Analysis and Probability and Statistics for Engineers 1 are both sophomore level courses, with mainly industrial engineering students enrolled. Biotransport Phenomena is a junior level bioengineering course. Transport Phenomena is a senior level course for chemical engineering students. Student enrollments in the courses are listed in Table 1. The MEAs used in this study were typically built into the course structure as "mini-projects" and the RTs were often assigned as bonus exercises in order to better assure compliance and participation.

MEAs are designed according to six principles as scaffolding for students to either: integrate, reinforce or discover new concepts[9]. The MEAs in this study were assigned after the concepts were first introduced in class (reinforce). Students worked in teams of three on the MEAs. Seven MEAs were used in the four courses. A brief overview of each MEA is included in Table 1. For additional examples of MEAs as well as guidelines for their use please see http://modelsandmodeling.net/Home.html. It should be noted that the MEAs used in the Probability and Statistics for Engineers 1 course (Tire Reliability, Test Leads and CNC Machine) and the Engineering Economic Analysis course (Campus Lighting, Trees and Road Safety, and

Dam Construction) are of shorter duration with an individual and a group part, completed in about a week's time. The wetsuit MEA used in the Transport Phenomena and Biotransport Phenomena courses has two group parts and takes about a month to complete. After the student teams turned in their solutions, they were awarded bonus points for individually completing the RT. The percentage of students who completed the RT in each course is listed in Table 1. At least half the students enrolled in each class completed the RT, with the highest percent completion being 95%. The reflection question responses are grouped into four categories: teamwork, problem solving, professional skills and technical concepts learned.

The four instructors who were interviewed have a range of teaching experience and familiarity with active learning techniques. Each had taught using MEAs before. Instructors 1and 2 did three MEAs in their respective courses, in the same department at the same university. Instructor 3 and 4 did the same MEA, but in two different courses at two different universities. Instructors 2 and 3 were less familiar with MEAs compared to the other two instructors.

Table 1: MEAs and student enrollments in the four courses

MEA Title	Decision Situation	Ethical Dilemma	Targeted Technical Concepts	Number of students in course	Percentage of students who responded
Campus Lighting Instructor 1	Select which lighting proposal is least costly and considers the safety concerns of the campus community	Weighing campus safety compared to the costs associated with a new lighting system	cost estimation, time value money, comparing alternative investments, B/C ratios, considering all relevant criteria, dealing with uncertainty	49	55%
Trees and Road Safety Instructor 1	Determining if old growth trees should be removed to provide more safety on a park road	Weighting environmental concerns compared to driver safety	cost estimation, time value money, comparing alternative investments, B/C ratios, considering all relevant criteria, dealing with uncertainty	49	51%
Dam Constructio n Instructor 1	Budget cuts impact how a major dam project should be completed in Turkey	Weighting the economic and water benefits compared to environmental and public relations concerns	cost estimation, time value money, comparing alternative investments, B/C ratios, considering all relevant criteria, dealing with uncertainty	49	71%
Tire Reliability Instructor 2	Develop a general procedure to analyze reliability of any set of tires based on "acceptable reliability" data set	Safety concerns about reliability of a tire production run	reliability, mean, median, standard deviation, histogram, probability plots, percentage, outliers	49	65%
Test Leads Instructor 2	Develop a sampling procedure to ensure a batch of test leads is acceptable dimensions, including the minimum sample size for the expensive product	Determining conditions under which a recall of defibrillators might be recalled	central limit theorem, uniform distribution, sample size, means, sample of the means, confidence intervals, variance, sampling distribution	49	63%
CNC Machine	Comparing the performance of two	Determining the weight of	hypothesis testing, standard deviation,	49	57%

Instructor 2	types of machines to determine if a new machine should be purchased	management's advice and reporting realistic results	confidence intervals, variance, central tendency		
Wetsuit Instructors 3 and 4	Develop a procedure to estimate how long a user can stay in the water depending on wetsuit material and thickness	Determining what safe conditions are so a wetsuit user does not get hypothermia	energy balance, steady-state process vs. thermal equilibrium, rate of energy transfer vs. amount of energy transferred, energy generation, heat transfer resistance, creating a physical model, creating an analytical model, geometry, energy conservation, heat generation (metabolism), conduction, convection, resistances in series, macroscopic vs. microscopic approach, linearization (from cylindrical to Cartesian), spreadsheet cells as "variables", movement of "data" between worksheets, "look and feel" of the sales rep tool	44 in Biotransport phenomena 96 in transport phenomena	95% 87%

Interviews

Three of the four structured interviews were done in the faculty members' offices and one was done over the phone. The interviews took between 45 minutes to one hour to complete. The students and instructors responded to the same questions (the instructor questions were modified from the RT assigned to the students). The interview questions are listed in the appendix. It should be noted that the responses to three interview questions are not included here (technical assumptions that students made about the problem, the two critical points on their solution path and the question about modeling skills). The interviewer's notes were transcribed and sent to the interviewee for review. The interviewees confirmed that the typed responses were correct and captured their opinions and perspectives accurately.

Results

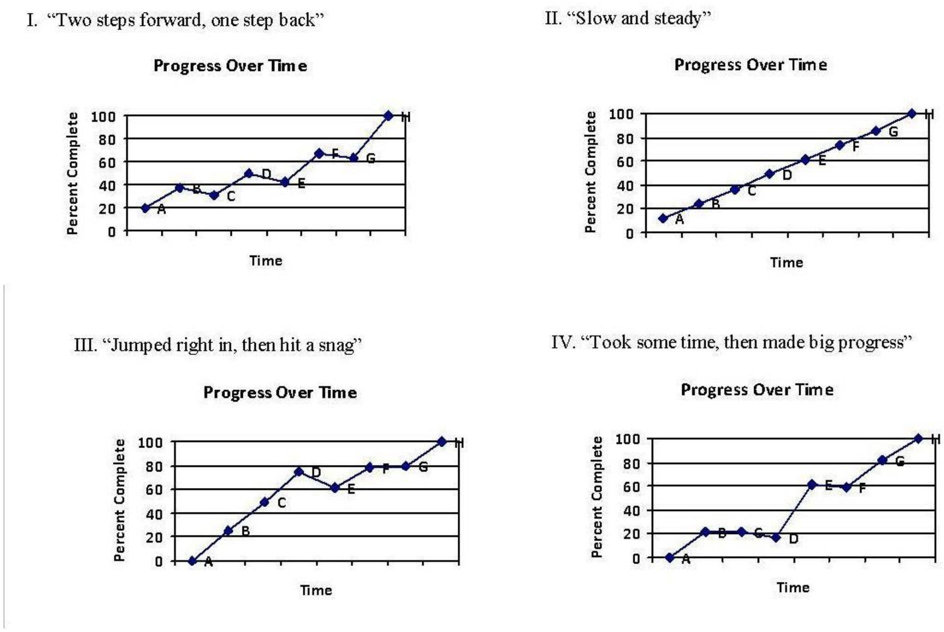
Student Responses

The student responses for each RT were tallied and summarized. Open ended responses were coded into categorizes, which were then tallied. For example, for the RT used for the Engineering Statistics MEAs, students listed their individual contributions to the problem solving process, which were categorized into one of the following: Excel spreadsheet/Minitab, writing the memo, ethical issue, calculations/analysis, group discussion/group leader/group organization, literature review/background information, or other.

The ABET professional skills were summarized into five categories: LLL (which includes recognition of lifelong learning, and other), context (which includes engineering in an economic, environmental, societal, and global context), communication (which includes communication skills), responsibility (which includes ethical and professional responsibility), and teamwork (which includes solving engineering problems, teamwork, working with realistic constraints, interpreting data, analyzing data, applying engineering concepts, using software and professional writing). For both the technical concepts learned and professional skills used, a majority of the students listed more than one of the keywords for each question.

It should be noted that there are three generations of Reflection Tools, and slight modifications have been made for the most current version. In Fall 2009, the RT version did not have multiple choice options for the team work process graphs. Analysis of student responses from previous generations of RTs were categorized, and based on the most common graph types became the four multiple choice options. The student responses were categorized into one of four graphs that represent the path their team took while working on the assignment, see Figure 1 below. Graph One's description is "two steps forward, one step back". Graph Two's description is "slow and steady". Graph Three description is "jumped right in, and then hit a snag" and Graph Four is "took some time, and then made big progress".

Figure 1: Graphs of team work process choices



<u>Instructor Perceptions of Student Responses to the Reflection Tool Questions</u>

An excerpt of the responses Instructor 1 gave during the interview is summarized below in Table 2. The comparisons to student responses are also listed, which includes only the top responses (or top two if the difference in number of responses was 2 or less). A discussion of the comparison of the two responses follows Table 2.

Table 2: Instructor 1's perception of student responses to reflection questions in the Engineering Economic Analysis Course

Reflection Tool Questions	**Instructor 1 perception**	**MEA specifics**	**Comparison to Student Responses**
Teamwork Process Most common graph	Graph 4: Took some time, then made big progress Non-linear path	For all three MEAs	Campus Lighting • 50% Graph 2 (slow and steady) • 50% Graph 4 (took some time, then made big progress) Trees and Road Safety • 42% Graph 2 (slow and steady) • 46% Graph 4 (took some time, then made big progress) Dam Construction • 55% Graph 2 (slow and steady)
Final solution: • Agreement • Satisfaction	Not much difficulty agreeing on final solution. The majority of the students will be most satisfied.	For all three MEAs	Campus Lighting • 84% no difficulty • 79% strongly agree Trees and Road Safety • 92% no difficulty • 63% strongly agree Dam Construction • 92% no difficulty • 60% strongly agree
Concepts Learned: • Technical concepts • Professional skills	Professional skills: • Using software • Analyze data • Realistic constraints • Solve engineering problems • Ethics • Global context (dam construction MEA only) • Societal context • Environmental context (trees and road safety MEA only) • Economic context	Campus Lighting • Cost estimation • Comparing alternatives Trees and Road Safety • Time value money • B/C ratios • Consider all relevant criteria Dam Construction • All of them except comparing alternatives • Dealing with uncertainty is the most commonly chosen	Campus Lighting • 43% context • 27% Consider all relevant criteria • 27% comparing alternatives Trees and Road Safety • 26% context • 31% B/C ratios Dam Construction • 29% context • 25% B/C ratios
Roles students play in teamwork process and individual contributions	Traditional group roles: leader, recorder, information gatherer, data cruncher, spreadsheet. Some individual students will "do everything" A team leader will decide on solution path and the team will go along with them. Differing		Campus Lighting • 48% excel/Minitab • 37% calculation /analysis Trees and Road Safety • 29% discussion • 24% calculation

	opinions will be resolved by a vote. It will not be decided by logistical analysis		/analysis Dam Construction • 58% calculation /analysis • 18% write memo
Noticed Ethical Dilemma	Campus Lighting • Issue was safety Trees and Road Safety • Issue was environmental concerns Dam Construction • Many issues	Campus Lighting • Small percentage Trees and Road Safety • Small percentage Dam Construction • Half the students	Campus Lighting • 58% yes Trees and Road Safety • 87% yes Dam Construction • 80% yes
Enjoyed experience	50/50 split for like and disliking the MEA		Campus Lighting • 58% somewhat agree Trees and Road Safety • 39% somewhat agree • 35% neutral Dam Construction • 44% neutral • 28% somewhat agree

Instructor 1 believed that the most common teamwork process would be characterized by "took some time than made big progress", or a non-linear path. The students responded that they took this path about half the time for both the Campus Lighting and Trees and Road Safety MEAs. Interestingly the students reported taking a "slow and steady" or linear path as the other choice for those two MEAs including the Dam Construction MEA. The students took a more "linear" teamwork problem solving path than the instructor thought was going to be the case. For both whether the students had difficulty agreeing on the final solution and their level of satisfaction with the answer, the instructor's perception was that there would not be much difficulty agreeing and that a majority of the students would be satisfied. This was indeed the case, with "no difficulty" being reported by 84% of the students for the first MEA and 92% for the last two MEAs. The students also reported "strongly agree" about being satisfied with their solutions, but it decreased from 79% to 63% to 60% over the three MEAs. This may be due to the nature of these MEAs in sequence; the ethical and context surrounding the MEA solution to have more complicated factors to consider.

Instructor 1 thought the most common technical concepts learned for all three MEAs would be: cost estimation, comparing alternative investments, time value money, B/C ratios, consider all relevant criteria, and dealing with uncertainty. For the campus lighting MEA, the students also listed comparing alternatives but they listed considering all relevant criteria. The students did not mention time value of money nor cost estimation as main concepts learned and emphasized benefit/cost ratios more than the instructor perceived. "Context" was the most common professional skill that the students listed for all three engineering economic analysis course MEAs, which is also what the instructor believed, however the instructor also included many other problem application skills such as using software, analyzing data and ethics. The roles that students played in their teams was not as traditional and straightforward as the instructor thought; students mentioned calculation and analysis for all three MEAs (increased from 37% to 58% from first to third MEA) which was not how the instructor thought the students would have decided their solution path. In the second MEA, trees and road safety the students mentioned discussion and writing the memo for the last MEA, showing how additional factors changed depending on the MEA and order of the MEA. The students got better at noticing the ethical dilemma in the MEAs (58%, 87% and 80% respectively). In comparison, the instructor thought only a small percentage would notice the ethical dilemma in the first two MEAs, and only half in the third MEA. Instructor 1 thought there would be a 50/50 split for liking versus disliking the MEAs. For the first MEA, a majority of the students (58%) somewhat agreed they enjoyed the experience, while over half either somewhat agreed or were neutral concerning the last two MEAs. Students might start to "get used to" MEAs over time, since they are very different from traditional homework problems where there is only one right answer with all the directions given directly from the beginning.

An excerpt of the responses Instructor 2 gave during the interview is summarized below in Table 3. The comparisons to student responses are also listed, which includes only the top responses (or top two if the difference in number of responses was 2 or less). A discussion of the comparison of the two responses follows Table 3.

Table 3: Instructor 2's perception of student responses to reflection questions in the Probability and Statistics for Engineers 1 Course

Reflection Tool Questions	**Instructor 2 perception**	**MEA specifics**	**Comparison to Student Responses**
Teamwork Process Most common graph	Depends on the group. If there is an academically strong student, he or she will become the leader and guide the group. If the group has a similar type of students, there will be more discussion.	Tire Reliability and Test Leads • Graph 1 (two steps forward, one step back) or Graph 4 (took some time, then made big progress) CNC Machine • Graph 2 (slow and steady)	Tire Reliability • 47% graph 4 • 27% graph 2 Test Leads • 63% graph 2 • 20% graph 4 CNC Machine • 39% graph 4 • 32% graph 3
Final solution: • Agreement • Satisfaction	If there is a leader in the group, then there will be no difficulty.	Tire Reliability • No strongly dissatisfied • Equally divided among the other categories Test Leads • Most students have incorrect solution • Large variety in solutions submitted CNC Machine • More students with a higher satisfaction	Tire Reliability • 78% no difficulty • 74% strongly agree Test Leads • 73% no difficulty • 65% strongly agree CNC Machine • 69% no difficulty • 72% strongly agree
Concepts Learned: • Technical concepts • Professional skills	Professional skills: • Solve engineering problems • Apply engineering concepts • Analyze data • Ethical responsibility	Tire Reliability • Mean • Standard Deviation • Reliability • Probability Plots Test Leads • Uniform distribution • Confidence Intervals • Sample Size • Central Limit Theorem CNC Machine	Tire Reliability • 25% reliability • 19% probability plots • 57% teamwork Test Leads • 32% confidence interval • 25% sample size • 43% context • 23%

		• Hypothesis Testing • Confidence Intervals	communication CNC Machine • 43% hypothesis testing • 41% responsibility • 26% context
Roles students play in teamwork process and individual contributions	There might be more discussion around the ethical issue. Groups might juggle between several solutions, but they should know if they are right or not.		Tire Reliability • 39% calculation /analysis Test Leads • 36% calculation /analysis • 22% write memo CNC Machine • 57% calculation /analysis • 23% write memo
Noticed Ethical Dilemma	60% to 70% will notice ethical dilemma		Tire Reliability • 70% yes Test Leads • 74% yes CNC Machine • 48% yes • 21% maybe
Enjoyed experience	50/50 split will enjoy doing it		Tire Reliability • 47% neutral • 27% somewhat disagree Test Leads • 36% somewhat agree • 32% neutral CNC Machine • 41% somewhat agree • 28% neutral

For Instructor 2's Probability and Statistics for Engineers 1 course, the teamwork graphs 2 (slow and steady, 27% and 63%) and 4 (took some time than made big progress, 47%, 20% and 39%) were most common responses, which is similar to Instructor 1's Engineering Economic Analysis Course. Although a difference was 32% of the students listed graph 3, "jumped right in than hit a snag" for the CNC machine MEA. However, Instructor 2 thought Graph 1(which was not mentioned by the students as a common response) and 4 would be the most common for the first two MEAs and Graph 2 for the third MEA. In regards to the final solution, overwhelmingly the students had no difficulty agreeing (78%, 73% and 69%) and also were very satisfied with their final solutions (74%, 65% and 72%). Instructor 2 thought the students would begin being more varied in their satisfactions, but have a higher satisfaction with the third MEA. It should be noted that the second MEA, test leads is slightly different than the other two MEAs in this course and is of a more theoretical nature. It is also the MEA that most students have an incorrect solution and that there is a larger variety of solutions submitted. This did not change student's levels of agreement or satisfaction with their final solutions.

In regards to the concepts learned questions, instructor 2 was only half correct in which technical concepts the students would list the most. For the tire reliability MEA, both instructor and students mentioned reliability and probability plots, but did not list mean and standard deviation as the instructor had hoped. This was similar for the test leads MEA, where both instructor and students mentioned confidence intervals and sample size, but the students did not list uniform distribution or the central limit theorem. For the third MEA, both instructor and students listed hypothesis test, but the students did not list confidence intervals. In regards to the professional skills, the instructor listed solve engineering problems, apply engineering concepts, analyze data and ethical responsibility. The students mentioned teamwork, context, communication and responsibility (none of which the instructor listed). There was a large disconnect between what concepts the instructor thought the students gained and what the students reported.

Instructor 2 also had are simplified view of the roles that students would play in their teamwork process, depending heavily on if there was a strong leader in the group (indicated by academic performance). The students listed calculation and analysis at least one third of the time for all three MEAs, and memo writing for about 20% for the last two MEAs. Perhaps the students changed their perception about the importance of a properly written memo after the first MEA. It should be noted that instructors 1 and 2 have had many discussions together about MEAs, and might influence each other's opinions. The first two MEAs had a noticed ethical dilemma at 70% and 74% but it dropped to 48% for the CNC Machine MEA. This might be due to the fact that the ethical dilemma is more subtle than with the other two MEAs in this course. Instructor 2 had a very accurate perception of how many of the students would notice the ethical dilemma. Both Instructor 1 and 2 thought that there would be a 50% split between liking and disliking the MEAs. For all three MEAs in Instructor 2's course the "neutral" response was listed at least about one third of the time. There was a shift from 27% somewhat disagreeing for the tire reliability MEA to having somewhat agree for 36% and 41% for the test leads and CNC machine MEAs. It is quite possible that the tire reliability MEA is the first MEA experience that these students have ever had, which might explain their somewhat dislike response.

An excerpt of the responses Instructor 3 gave during the interview is summarized below in Table 4. The comparisons to student responses are also listed, which includes only the top responses (or top two if the difference in number of responses was 2 or less).

Table 4: Instructor 3's perception of student responses to reflection questions in the Biotransport Phenomena Course

Reflection Tool Questions	**Instructor 3 perception**	**MEA specifics Wetsuit MEA**	**Comparison to Student Responses**
Teamwork Process Most common graph	Modification of Graph 4. Progress motivated by deadlines. Students may or may not take feedback into account		• 36% Graph 2 • 28% Graph 4
Final solution: • Agreement • Satisfaction	No difficulty in final solution agreement. Satisfaction will be 8 out of 10.		• 62% no difficulty • 40% somewhat agree • 38% strongly agree
Concepts Learned: • Technical concepts • Professional skills	• Professional skills: • Solve engineering problems • Using software • Apply engineering concepts	• Creating a physical model • Energy balance • Heat transfer	• 40% Macroscopic vs. microscopic approach • 52% professional

	• Teamwork • Professional writing	resistance • Geometry • Heat generation/metabolism	writing
Roles students play in teamwork process and individual contributions	Depends on the team, since students pick their own teams. Well-functioning teams will divvy up the work. Less functioning teams will have a leader, or one person doing a majority of the work	The student with the clearest vision of the solution will lead the team. Once the team agrees on a solution plan, all team members will put some effort in.	78% calculation /analysis
Noticed Ethical Dilemma	The value of human life will be looked at as a constraint. Everyone will discuss this, but not in terms of "ethics" per say		45% No
Enjoyed experience	Most enjoyed it.	I am doing another modeling experience again in another class, which demonstrates how important these exercises are	• 31% Neutral • 28% somewhat agree

Instructor 3 perceived a modification of Graph 4 for the students in their teamwork process "took some time then made big progress". About one third chose graph 4 and another third chose graph 2 ("slow and steady"). In regards to the final solution, Instructor 3 thought there would be no difficulty in agreeing on the final solution, and that the students would have an 80% satisfaction rate. The students reported 62% having no difficulty in agreeing on a final solution, lower than what the instructor perceived. 40% somewhat agreed and 38% strongly agreed that they were satisfied with their final solution. In regards to the concepts learned, 40% of the students listed macroscopic vs. microscopic approach as most often chosen concept, whereas Instructor 3 did not but listed several others instead: creating a physical model, energy balance, heat transfer resistance, geometry and heat generation/metabolism. 52% of the students listed professional writing as the skill they used the most, which was one of the professional skills the instructor perceived as well. Instructor 3 also had four other professional skills: solve engineering problems, using software, apply engineering concepts and teamwork. Like the other two courses, students in Instructor 3's course listed calculation and analysis as the main role they played in their teamwork process, although this was significantly higher at 78% of the students responding to this concept. The Wetsuit MEA was not initially designed as an E-MEA or MEA with an ethical component, but there are ethical considerations to the problem for if the calculations are incorrect, it could result in a diver getting hypothermia in the scenario. Therefore the ethical dilemma is not as clear for the Wetsuit MEA compared to the other MEAs used in the other courses, resulting in 45% of the students responding that they did not notice the ethical dilemma. Instructor 3 recognized this, and noting that the students would not label it as "ethics". About one third of the students responded that they were neutral about enjoying the MEA experience, and 28% somewhat agreed. The instructor thought that most students would enjoy the Wetsuit MEA. It should be noted that the instructor in this course gave supplemental materials (a PowerPoint slide) to the students on both report/memo writing and "steps in a general modeling procedure", which contributes to consistency in the students' problem solving approaches.

An excerpt of the responses Instructor 4 gave during the interview is summarized below in Table 5. The comparisons to student responses are also listed, which includes only the top responses (or top two if the difference in number of responses was 2 or less).

Table 5: Instructor 4's perception of student responses to reflection questions in the Transport Phenomena Course

Reflection Tool Questions	**Instructor 4 perception**	**MEA specifics Wetsuit MEA**	**Comparison to Student Responses**
Teamwork Process Most common graph	Steady, step by step approach, Graph 2. The senior level students will have a broader perspective, discipline and experience		53% Graph 2
Final solution: • Agreement • Satisfaction	Teams will not have much trouble agreeing on a final solution.	• 15-20% strongly satisfied • About 30% satisfied • 30-40% neutral • 5% unsatisfied • 1 person will be strongly dissatisfied	• 94% no difficulty • 78% strongly agree
Concepts Learned: • Technical concepts • Professional skills	Professional skills: • Formulate and solve engineering problems • Applying math, science or engineering knowledge • Apply engineering tools (students will think of the spreadsheet as a tool)	• Energy balance • Energy generation • Heat transfer resistance • Creating an analytical model • Geometry • Heat generation/metabolism • Convection • Resistances in series	• 50% creating an analytical model • 38% heat transfer resistance • 40% Working with realistic constraints • 37% apply engineering concepts
Roles students play in teamwork process and individual contributions	Facilitator, memo writer and technical role (doing the math, spreadsheet, etc.). Team will take one solution idea and "run with it".	Teams will come to a decision point, make the decision and move on.	83% calculation/analysis
Noticed Ethical Dilemma	50% of the students will notice the ethical situation	Students should talk about the very obvious ethical issue with worrying about hypothermia.	61% No
Enjoyed experience	1/3 students enjoyed the experience, but maybe pessimistic.	Students like it because it was "not just another homework". I had fun doing the MEAs with the students.	59% Agree

Instructor 4 was correct in the perception that most of the students would take the step by step team work process approach, and 53% of the students responded the same. Instructor 4's course had the highest percentage, 94% of the students responded having no difficulty in agreeing on their final solution (although the Trees and Road Safety and Dam Construction MEAs had student responses over 90%). The students had a much higher satisfaction level with their final solution than the instructor perceived, with 78% strongly agreeing compared to 15-20%. The two technical concepts that the students listed, 50% creating an analytical model and 38% heat transfer resistance were both mentioned by Instructor 4. Instructor 4 also listed: energy balance, energy generation, geometry, heat generation/metabolism, convection and resistances in series. 37% of the students listed apply engineering concepts as one of the professional skill they used the most, which is also what the instructor perceived. The students also listed working with realistic constraints 40%, which is not a professional skill that the instructor perceived. In team member roles like all the three other courses, students emphasized calculation and analysis with 83% of the students listing this skill. Instructor 4 perceived that half of the students would notice the ethical situation, but 61% of the students said that they did not notice it. 59% of the students agreed that they enjoyed the Wetsuit MEA, which is higher than the one third the instructor perceived. It should be noted that the students in Instructor 4's course were seniors, which assumes they have had more practice using some of the professional skills compared to the juniors in Instructor 3's course and the sophomores in Instructor 1 and 2's courses. This is also a view held by Instructor 4.

Discussion

The majority of the instructors selected graph 4 and graph 2 as their perception of the other common student response. The students chose these most often as well. Results seem to indicate that the students did not have any difficulty agreeing on their final solutions and that overall students were satisfied with the final solutions. The concepts learned were not as clearly connected between the instructor's perception and their students' responses. It appears that what the instructors thought the main technical concepts were, often were not top on the list of responses by the students in their respective courses. The students most often reported "context" as the professional skill they learned (which includes engineering in an economic, environmental, societal, and global context). Instructors described "traditional" team functioning, such as having a "leader" that guides to the final solution. Instructors also indicated the likelihood of more discussion and grappling with the ethical issue than what might occur. Students mostly listed calculation and analysis as their main contributions to their team, with memo writing becoming more prominent in the later MEAs. The students did notice the ethical dilemma, or they reported that they did. In regards to the overall enjoyment of the MEA experience, about one third of the students "somewhat agree" in the first course, and the second course had more "neutral" responses.

Instructor 1's perceptions aligned with the student responses on aspects of the final solution (agreement and satisfaction) and that the professional skill of context was practiced by the students. There was a disconnect on teamwork process (more linear of a process than the instructor thought), on some technical concepts (students did not mention time value money or cost estimation but emphasized benefit cost ratios more than the instructor realized) and the students reported using calculations and analysis in their teamwork roles, but this is not how the instructor 1 thought decisions would be made.

Instructor 2's perceptions aligned with the student responses on aspects of the final solution (agreement and satisfaction) and also how the students would notice the ethical dilemma. There was a disconnect on team process (instructor 2 perceived two steps forward, one step back but the majority of students did not mention it), there was a half connection with the technical concepts that the students listed they primarily learned, and also the professional skills that instructor 2 mentioned the majority of students did not.

Instructor 3's perceptions aligned with the student responses on the professional skills utilized and the noticing of the ethical dilemma. There was a disconnect of perception and student responses to the technical concepts for instructor 3. Instructor 4's perceptions aligned on the step by step team process that the students reported using, and also aligned perceptions with the student reporting of technical concepts and professional skills. There was a disconnect on instructor 4's perception of satisfaction (higher level than instructor 4 perceived) and on noticing the ethical dilemma.

Two points on which the instructors "underestimated the students" were in noticing the ethical issue and in gaining teamwork skills. Two instructors felt that a student's academic performance (grade point average) was the strongest indicator of success on the MEAs. These same two instructors felt that there are two "types" of students: students who get discouraged with non-traditional homework assignments and students who "like a challenge". It should be noted that all of the instructors for these courses have continued to incorporate MEAs as part of their teaching, even is some students get discouraged.

MEAs are designed according to six principles as scaffolding for students to either: integrate, reinforce or discover new concepts[9]. Differing emphasis on certain aspects of the MEA or course might be the source in variety of which technical and professional skills the students reported learning. It might also be due to sequences of courses taken or required courses. For example, whether or not the students have taken a writing course or which sections of a particular pre-requisite course (some instructors emphasize software such as excel or Minitab more than others).

Although there are only four instructors and their courses represented here, this process does give further insight into how students solve problems, the skills their teams use, and which technical concepts and professional skills they used most often. This knowledge would not be gained easily from a more traditional homework and gives instructors deeper insight into their students and where misconceptions could occur or technical concepts that would need more emphasis.

Conclusion

To answer the questions, "are the instructors aware of what students are learning from an MEA experience?" and "does their perception and expectations align with what the students report in reflections after their final solution is turned in?" It seems both yes and not always quite correct. Instructors have an impact on the learning in the classroom, and the instructors need to have many and high perceptions. Students have a majority of agreement on learning only a few items, but the reported learning on other concepts and skills varies widely. An instructor having so many expectations of their students learning helps to ensure that all students are achieving not only some of the main concepts but other important professional skills as well. While incorporating MEAs requires some additional effort on part of the instructors, this teaching method can help students practice applying technical concepts in a problem solving scenario that is rich with professional skills. Students learn many concepts from completing MEAs, but some more than others than their instructors perceive.

Acknowledgements

This research is supported in part by the National Science Foundation through DUE 071780: "Collaborative Research: Improving Engineering Students' Learning Strategies through Models and Modeling."

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Appendix-Interview Questions

Going to ask you a few questions about what you think students respond to the reflection tool questions after they have completed an MEA (answer for each MEA).

1. What do you think are the most common problem solving processes that the team of students will take? Please draw your own graph and fill it in.

2. What assumptions do you hope that students will make in forming their solution? Please outline both content based (statistical, engineering economy, bioengineering, etc.) and problem/context assumptions.

3. What types of roles do you think the students will most commonly participate in the teamwork process?

4. Do you think student teams will have difficulty agreeing on a final solution? If so, how do you think the teams will select their final answer?

5. Do you think the student teams will formulate many suggestions that do not make it into their final solution? If so, what would they be? Additionally, what other things do you think can or should make it into a final solution but often do not on a routine basis?

6. What level of satisfaction do you think most students will have with their solution? For example, what percentage will be strongly satisfied, somewhat satisfied, neutral, somewhat dissatisfied, strongly dissatisfied?

7. About what time, level of involvement and what problem solving stage do you think most students will be in at the first critical point? The second critical point? For example, what percentage will be high, medium, low or no involvement?

8. What targeted engineering concepts do you think most students listed that the MEA helped them learn? (Will provide the list for each MEA)

9. What ABET skills do you think most students listed that the MEA helped them learn? (Will provide the list)

10. What percentage of students do you think noticed the ethical dilemma? How do you think students described the ethical issue?

11. How do you think the students responded to the modeling question? How do you think they described what modeling is, and how their skills could be applied to other situations?

12. What percentage of students who responded do you think enjoyed doing the MEA?

Wrap up: What do you think are the main/specific/certain variables that influence the reflections the most, or that you have not already mentioned?