What's Muddy vs. What's Surprising? Comparing Student Reflections about Class

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Introduction

Classroom assessment techniques that ask students to reflect on material covered in class are believed to help improve learning by allowing the student to actively participate in the learning process while evaluating their understanding of course content.[1] Promoting students to be more reflective about their learning experiences allows them to develop robust learning strategies and metacognitive skills that are characteristic of expertise.[2] Students' written reflections can also provide instructors with formative information about students conceptions of course content. In this paper, we use the definition of Turns and Atman that reflection is the act of "exploring the meaning of experiences and the consequences of the meanings for future action."[3]

Instructors have used several forms of short reflection activities at the end of class. In this paper we compare two such activities which we term *Muddiest Point* and *Most Surprised*. Muddiest Point asks the students to answer the exit question, "What was the muddiest point in class this week?" In this activity, the instructor asks students to write a brief, anonymous written comment describing the concept or topic that they found to be the most difficult to understand during class. Similarly, in the Most Surprised reflection activity, the instructor asks students to answer the question "What surprised you most about class this week?" In this study, we use a quasi-experimental design to empirically investigate students' in-class responses to these two end of in-class activities where students were asked to reflect on the class over the last week. One recitation section is provided the more common *Muddiest Point* exit question. The alternate section is provided the *Most Surprised* exit question. We ask the research question, "How do the student reflection responses differ based on the type of exit question asked?"

Our hypothesis is the different reflection prompts will elicit different types of thinking about the class, but that both will provide the learners and the instructor productive information. By understanding the differences in how students answer these reflective exit questions, instructors can more intentionally select exit questions appropriately.

Background

Instructors have used several short end-of-class reflection activities to both promote student learning and gather formative information about students' conceptions of course content. Prompts include requesting students to describe the most important,[4-6] interesting,[7] confusing or muddiest,[5-10] and surprising[11] aspects from a lecture, recitation, or week of the course. In this paper we focus on the latter two.

Some of the early uses of the Muddiest Point activity focused on providing formative information for the instructor. For example, Mosteller[4] reported on the use of the Muddiest Point activity in a statistics class and argued that the practice "…promotes concrete and sometimes non-trivial responses to the question of what 'you want to know

more about'"(p. 19). A few years later Angelo and Ross[5] described the muddiest point as having one of the best returns on investment; although very little time is required to perform a Muddiest Point implementation, it can yield useful information for evaluating a class.

More recent studies emphasize the use of the Muddiest Point activity to promote student learning, particularly metacognition. For example, Tanner[7] found that assigning a Muddiest Point activity helps students realize that being confused is a natural aspect of learning. This activity also was found to allow the students to safely share what they find unclear without having to reveal their confusions to the entire class and thus risk judgment. Tanner argued that while students might be unaccustomed to being open with their professors about their confusions, the process of acknowledging, embracing, and resolving their misconceptions is a key to evolving as learners.

Hall and colleagues[6] report on a study in the context of increasing active learning in an engineering class. That study incorporated activities such as concept tests, group discussions, and Muddiest Point evaluations across several different engineering disciplines. They found that a majority of professors and students found Muddiest Point evaluations to be effective. Students felt that the professors' clarifications about the Muddiest Points directly improved their learning, showed their professors cared, and enhanced their overall relationship with their professors. The exercise was also popular amongst professors; several planned to include the exercise in their future courses. In Introductory Materials courses, Krause and colleagues[8,9] found the use of Muddiest Point activities informed instructors' use of formative process feedback and improved student attitudes, achievement and retention of course content.

Most Surprised activities are rarely used in engineering, but have been used by instructors in other fields in a way similar to Muddiest Point. In the most common form reported in the literature, Most Surprised is posed as one question in Brookfield's[11] five-question critical incident questionnaire (CIQ). The CIQ is intended to be assigned to students at the end of a course period or week of a course, in a similar manner to the Muddiest Point activity. In the CIQ, Most Surprised comes as the fifth and final item and is proceeded by questions regarding when students felt most engaged and least engaged, and what actions taken in class were most confusing and most affirming.

The use of the CIQ has been reported in many different educational settings, including health education,[12] adult online education,[13] public communication,[14], writing,[15] management education,[16] and engineering mechanics.[17] Generally the CIQ has been described as a useful instructional tool that promotes learner reflection. However, studies that explicitly assess the tool's effectiveness in various settings are lacking.[18]

Hessler and Taggart[15] reported that the CIQ solicited responses related to issues with pedagogical approaches rather than related to course content. In addition, they suggest that students' regular completion of the CIQ, including the Most Surprised question, helped students develop habits of a reflective practitioner and gave the instructor information to improve instruction. They noted that responses to the Most Surprised

question were often related to times students reported feeling most engaged, disengaged, or affirmed in the course. While most implementations have used the original questions, Keefer[19] suggested a revision of the CIQ that omits the Most Surprised question and instead asks students to identify the most important information learned in class and solicits questions or suggestions from the instructor. However, this revision has not been well tested.

While both the Muddiest Point and Most Surprised have been noted as providing instructors with formative assessment information and promoting students' critical reflection, there is little research on using Most Surprised as a sole reflection prompt and also little research comparing these exit questions. Our study seeks to provide a better understanding of the types of responses elicited by these questions so that instructors can select the exit question appropriately.

Methods

Our quasi-experimental study empirically investigates students' in-class responses to weekly reflection prompts. Participants were enrolled in a sophomore-level course titled "Material Balances and Stoichiometry" at a large public university in the Northwest United States. The course is a requirement of chemical engineering, bioengineering, and environmental engineering degree programs. It is the first of a three-course sequence that is followed by "Energy Balances" and "Process Data Analysis." Being the first department-specific requirement in the curriculum, the course also serves as the entry point for transfer students. Data are only reported for students who agreed to participate and signed an informed consent form approved by the Institutional Review Board.

The students attended a common lecture and self-selected into one of two weekly, one-hour recitations. There were 117 and 150 students that consented and wrote at least once response in recitation sections 1 and 2, respectively. Each week students were asked to provide responses to one of the following reflections in class:

1. What was the muddiest point in class today/this week? (Muddiest Point)
2. Describe what surprised you most in class today/this week (Most Surprised)

The questions were posed to students in the last five minutes of recitation with the objective that students would reflect on all of the previous week's activities. Each recitation section was asked to respond to both prompts, but in alternating weeks. So in a given week, one recitation section would answer the Muddiest Point while the other answered the Most Surprised. For example in Week 2, students in the recitation section 1 were asked the Muddiest Point and section 2 the Most Surprised. During the subsequent weeks, the Muddiest Point and Most Surprised were assigned alternatingly to the recitation sections. This research design allows us to compare the resulting student reflections based on the same content and coverage. Students provided responses on their laptops, smartphones, or tablets using the *Concept Warehouse*[20] where they were stored in a database and available for analysis.

Word count data and thematic codes and were obtained from the collected responses. The word count data served as a proxy measure of engagement. These data were used to

determine if one of the questions prompted more elaboration from students than the other question. The thematic coding provided a qualitative analysis of the student responses. This assessment allowed us to compare the content of the responses each prompt elicited. As stated above, Most Surprised in the context of the CIQ seldom provided content specific elaboration. We are interested to see the proportion of responses that address content relative to structural and pedagogical issues and, of those that address content, how they compare to the Muddiest Point. The coding process also provided information relative to affective differences in the responses.

Word counts for each of the approximately 1600 responses were computed and used for broad comparison of the entire dataset. We then used an emergent coding scheme on the subset from second and fifth weeks to more finely compare the results elicited by the two different prompts. These weeks were chosen because we had complete data sets (i.e., each section answered one of each reflection question), they were not the week of an exam, and they were as early in the term as possible.

We analyzed responses using open coding, a process used to infer categories of meaning. The coding process involved reviewing the responses and sorting them into categories. Initially, each set of data was scanned for reoccurring responses that could be used to generate the coding categories. After the first set of categories were created, there were a few responses left without a category. If these responses could be related to one another, a new category was created for them. When all of the remaining responses were unconnected both to each other and to existing categories, they were coded with the catch-all category “Other.”

Categories that were general and applied to both Week 2 and Week 5 data are shown in Table 1, along with a description of the code and examples reflections from each prompt. Not all codes were observed for both prompts; in such a case, only one example is given. Categories for week specific content are shown for Week 2 and Week 5 in Tables 2 and 3, respectively. For example, during the second week the concept of buoyancy was frequently identified in both the Muddiest Point and Most Surprised. The categories in Table 1 are general and can be interpreted in the context of any engineering science course. The categories in Tables 2 and 3 are topic-specific and meant to provide a comparative example of how content changes with prompt.

The first 50 responses for each prompt (100 total) in Week 2 were independently coded by two of the authors. Inter-rater reliability using the Cohen’s Kappa statistic is 0.94 for Muddiest Point and 0.92 for Most Surprised. This shows acceptable reliability for the coding process.

Table 1. General coding categories for reflection prompts

Category	Description	Examples	
		Most Surprised	**Muddiest Point**
Class/HW	Responses relating to the structure of the class, studios, or homework that has been assigned.	How fast you went in Monday's lecture. By the end I was pretty much writing down symbols I didn't know the meaning of.	I think the lectures were overall good, but there are some problems in the hw that was hard
Misconceptions	Responses in which students explained the material introduced in the class changed the way they previously thought about certain concepts/ideas.	I'm most surprised by the fact that for the conceptual questions the answer sometimes goes against my first instinct.	
Nomenclature	Responses involving the symbols or terms used in the class. This category also includes trouble writing symbols correctly.	I was surprised by the amount of vocabulary that goes into defining systems and processes	The muddiest point was pounds/pound mole. Is pound mole a completely different thing than pound*mole? It's just a strange unit.
Previous Knowledge	Responses relating the material in class to concepts that a student has learned in a previous class.	I really enjoy the chemistry concepts. I was surprised most about how you cane easily relate chemistry into the systems	
Problem Solving	Responses relating to the process of solving problems within the class.	That balancing processes is a much simpler process when looked at one step at a time.	setting up the equation to answer for the flow rate for problem C
Test	Responses focusing mainly on midterm exams.	That we have a midterm next week.	My midterm score ....
Specific Content	Responses relating to specific content covered in class. See Tables 2 (Week 2) and 3 (Week 5).	See Tables 2 and 3	See Tables 2 and 3
Positive	Responses with positive connotations.	How I'm starting to finally understand more!	At first the weird extent of reaction, but now I think I have a firm grip on that!
Negative	Responses with negative connotations.	most of the lecture material is easy to understand but the work part seems much harder and this freak me out.	I thought that studio was quite difficult - I would appreciate a hint or a general overview of concepts we will need before we begin.
Neutral	Responses with neither positive nor negative connotations.	that when ice met it does not change the over all water level of a glass afterwards.	Differentiating between the types of process'
Other	Responses that have nothing to do with the class or the material that was covered.	I was surprised by the amount of people talking during our lecture.	When it rained outside, that was pretty muddy.
Nothing	When a student finds nothing surprising or muddy.	Nothing is really surprising in this week.	I understood everything fine

Table 2. Week 2 content specific coding categories for reflection prompts

Week 2 (Specific Content)			
Category	**Description**	**Examples**	
		Most Surprised	**Muddiest Point**
Balances	Responses focusing on the process of performing material balances on a system	The in-depth process that needs to be taken to figure out the material balance equation	
Buoyancy	Responses involving buoyancy and other related principles such as Archimedes' principle and buoyant forces	Throwing the rock out the boat and having the water displaced decrease instead of staying the same or increasing.	The problems that involve buoyant force like the one with melted ice.
Mole/Mass	Responses focusing on concepts of mole/mass fraction		I have some difficulty converting from mass fraction to mole fraction etc...
Pressure	Responses regarding pressure concepts.	Differences in the types of pressure(gauge, absolute, and atmospheric.)	The gauge pressure relating to atmospheric/absolute pressure
Processes	Responses involving typical chemical engineering process or types of reactors		The new notes that we took today about batches and the way they work
Other Concepts	Responses that relate to material covered in class but that cannot definitively fit into any of the above categories. Most of these responses are only mentioned once.	The formula of volume seems very useful and interesting.	The lecture when we talked about the ideal gas law and what that had to do with what we are talking about

Table 3. Week 5 content specific coding categories for reflection prompts

Week 5 (Specific Content))			
Category	**Description**	**Examples**	
		Most Surprised	**Muddiest Point**
DOF	Responses regarding determining degrees of freedom and distinguishing implicit and explicit equations	DOF = Unknowns - species - other independent equations; finally made sense	I learned in lecture that there are implicit and explicit equations that make up the total number of equations accounted for in the degrees of freedom analysis.
Extent of Reaction	Responses regarding the extent of reaction or related concepts	How useful the extent of reaction is in terms of solving the material balances.	zi was kinda confusing, what does it actually represent
Fractional Conversion	Responses relating to fractional conversion. Some included the relationship between fractional conversion and extent of reaction while others involved the relationship between fractional conversion and the amount of remaining moles of a specific species	How intuitive fractional conversions are, most of the work can be derived even without knowledge... key word MOST	how to find the # of moles with a remaining amount
Mass Fraction Eq.	Responses involving the summation of mass fractions being equal to one. This was often double-coded with DOF.	I learned that you can use sum of Xi=1 for each stream instead of only once per subsystem.	
Multiple Streams	Responses regarding processes with multiple streams; these include problems involving recycling and bypass.	bypass	My muddiest point was determining that the composition of a flow split was equal at all parts.

Table 3 (continued). Week 5 content specific coding categories for reflection prompts

Week 5 (Specific Content))			
Category	**Description**	**Examples**	
		Most Surprised	**Muddiest Point**
Reactions/MB	Responses focusing on preforming material balances on reactive species	The ability to use chemical equations and relate them to flows.	just in general incorporating the reactions into the balances and stuff. having a rough time picking up concepts and applying them
Rxn Rate	Responses including reaction rate and related principles	That the reaction rate can be generalized to an entire set of species.	
Other Concepts	Responses that relate to material covered in class but that cannot definitively fit into any of the above categories. Most of these responses are only mentioned once.		The equilibrium material.

Results

Word Count Analysis

Figure 1 presents a series of boxplots showing the distribution of the word counts of responses by the week of the term and the type of reflection. The first data shown are from Week 2 since reflections were not administered the first week of the term as it was too close to the start. Week 3 is not shown because data are missing for the Muddiest Point due to a fire drill during that section. Approximately 1,600 student reflections were collected over the term. Students averaged 6 responses with a standard deviation of 3 responses.

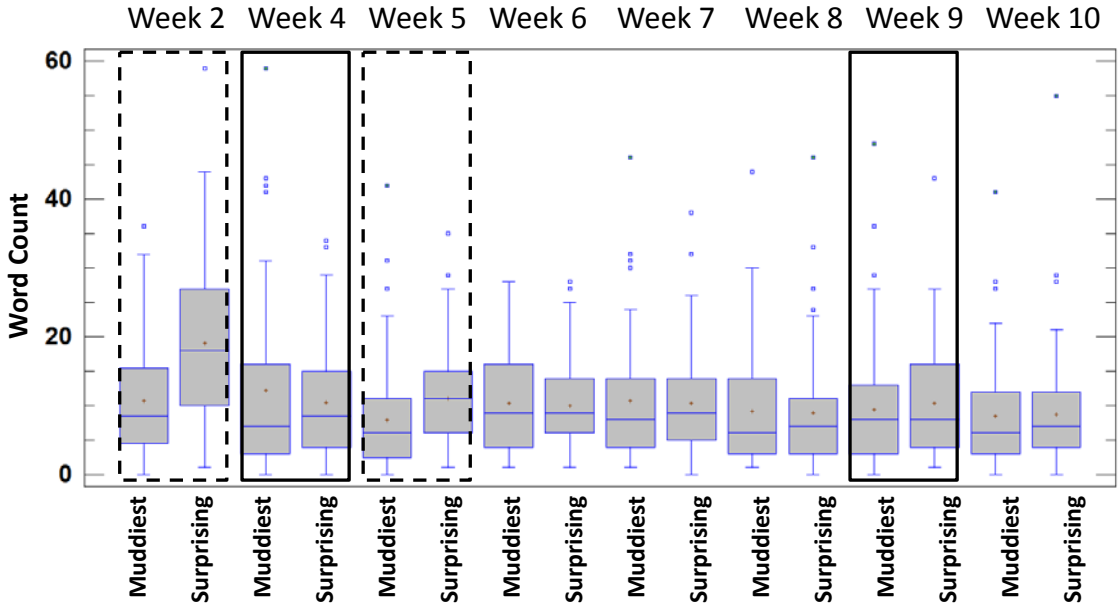


Figure 1. Box plots of Muddiest Point (Muddiest) and Most Surprised (Surprising) word counts over the 10-week quarter. The dashed boxes are the two sets that were coded in the study. The solid boxes correspond to weeks that there was a midterm exam.

One-way ANOVA was used to compare the word count by week. Week 2 ($P < 0.001$) and Week 5 ($P < 0.003$) had statistically significantly different counts with the Most

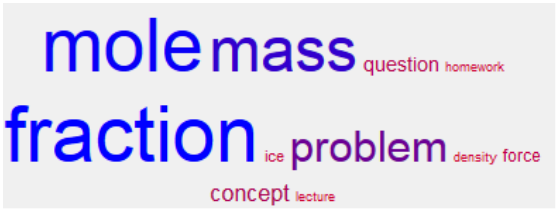
Surprised prompt eliciting more words, irrespective of section. It could be interpreted that Most Surprised elicits a higher level of engagement. In Week 2, Section 2 responded to the Most Surprised prompt. In Week 5, Section 1 responded to the Most Surprised prompt.

Midterm exams were administered in Weeks 4 and 9 (shown with solid boxes in Figure 1). Correspondingly, the exams became a focus in these weeks with 58 and 78 responses, respectively, that referred to "test"," exam," "quiz," or "midterm," possibly explaining the similarity in length. Additionally, the difference in word count between prompts reduced as the quarter proceeded. We speculate the students may have started to pay less attention to the instructions as they became familiar with both prompts. Alternatively, data from earlier in the term may simply be anomalous. To further probe differences in responses from the prompts we qualitatively analyzed data from early in the term, described next.

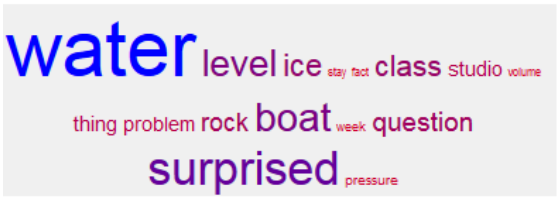
Coding Analysis

Reflection responses from Weeks 2 and 5 were coded using definitions from Tables 1-3. An overview of the responses in the form of word clouds[21] is shown in Figure 2.

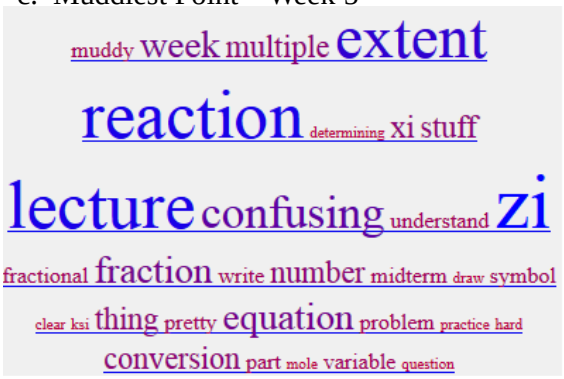
a. Muddiest Point – Week 2



b. Most Surprised – Week 2



c. Muddiest Point – Week 5



d. Most Surprised – Week 5

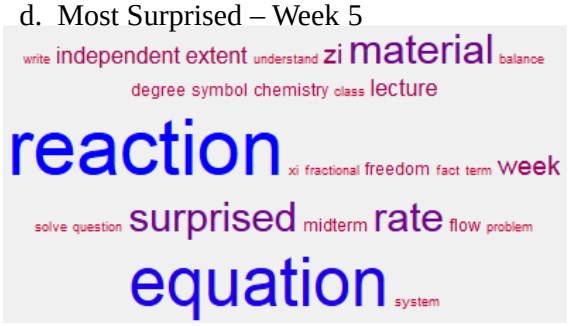


Figure 2. Word clouds of Muddiest Point and Most Surprised for weeks 2 and 5.

Table 4 shows counts for codes that are general to both weeks. In some cases, a response received several codes. Approximately 60% of the responses focused on specific content. There were 35 responses total in the code "Class/HW" early in the term (Week 2) and only 5 by Week 5. While the reference to "Test" were significantly reduced compared to Week 4, there were still 20 responses in Week 5 divided evenly between the two reflection prompts. The Most Surprised prompt elicits responses to pedagogically-oriented reflections not seen in the Muddiest Point responses such as "Misconception"

and “Previous Knowledge.” On the other hand, there is a greater reference to “Problem Solving” in the Muddiest Point responses (11 vs. 2).

Table 4. General coding counts for reflection prompts

Code Count				
Category	**Week 2**		**Week 5**	
	Most Surprised (Section 2) n = 134	**Muddiest Point (Section 1)** n = 111	**Most Surprised (Section 1)** n = 100	**Muddiest Point (Section 2)** n = 113
Class/HW	21	14	3	2
Misconception	10	0	0	0
Nomenclature	0	6	10	10
Previous Knowledge	13	0	6	0
Problem Solving	2	6	0	5
Specific Content	86	85	61	74
Test	0	0	10	10
Other	14	4	5	13
Nothing	2	7	5	14

Tables 5 and 6 show the specific coding counts for Weeks 2 and 5, respectively. In general, the cumulative student reflection show them struggling with similar content with “Buoyancy” receiving the most responses from each prompt in Week 2 and “Extent of Reaction” in Week 5. Clearly these are topics the instructor should provide additional resources for students to learn. The code “Mole/Mass” received a high number of counts for the Muddiest Point in Week 2, but no responses for the Most Surprised. Examination of recitation activity indicates that there was a concept question that asked students to estimate mole fraction of a mixture given the mass fraction. This question was given at the end of Section 1, but there was not time to ask it in Section 2. The “muddiness” of the students with this response may be, in part, due to lack of time to consider the question fully. Instructors should keep contextual factors like this example in mind when interpreting responses.

Table 5. Week 2 content specific coding counts for reflection prompts

Code Count		
Category	**Week 2**	
	Most Surprised	**Muddiest Point**
Buoyancy	59	32
Mole/Mass	0	29
Pressure	17	8
Processes	5	6
Application	0	6
Other Concepts	5	4

Table 6. Week 5 content specific coding counts for reflection prompts

Code Count		
Category	**Week 5**	
	Most Surprised	**Muddiest Point**
Extent of Reaction	24	40
Reactions/MB	11	9
Fractional Conversion	4	12
Degrees of Freedom	11	3
Multiple Streams	2	6
Reaction Rate	5	0
Mass Fraction. Eq.	4	0
Other Concepts	0	4

Table 7 presents coding counts for responses that are clearly positive or negative. In both cases, the majority of responses were coded neutral. However, while the Most Surprised is divided almost equally between positive and negative, the Muddiest Point is more frequently negative. This result has implications to the type of class environment it produces and should be considered by instructors when using reflection prompts.

Table 7. Coding counts for positive, negative, and neutral reflection prompts

Code Count				
Category	**Week 2**		**Week 5**	
	Most Surprised (Section 1)	**Muddiest Point (Section 2)**	**Most Surprised (Section 2)**	**Muddiest Point (Section 1)**
Positive	20	4	25	6
Negative	17	19	25	22
Neutral	98	88	49	85

Specific Responses

We consider next responses for the most common content-specific category from Week 2, buoyancy. For context, in the recitation that the reflections were collected, a conceptual question was asked in which the students were asked to predict how the level of liquid water compares for a system initially composed of ice water to the level of the same system after the water melts. The normatively correct response recognizes that the ice is initially partially submerged at the water interface and applying the principle of buoyancy reasons that there is no change in water level after it melts.

The following shows Most Surprised and Muddiest Point responses that appear to refer to that question. They are selected for a specific case, but are representative of the general type of differences we observed for each prompt. For the Most Surprised prompt, students responded:

- "…The ice being the same volume when melted"
- "The ice cubes melting causing the water level to stay the same"
- "The fire! Not actually, honestly, it was this question from today about the level of water and ice---initially puzzling, but then it makes sense in principle!"

From the buoyancy-coded responses to Muddiest Point, students responded:

- "The problems that involve buoyant force like the one with melted ice."
- "The rock on the boat problem and the ice cube problem in recitation. Having difficulty figuring out the change in water level when objects are added/removed/submerged in a liquid"
- "The image in the ice melting question was misleading because the ice appeared to be fully submerged."

From an instructor's perspective, it is harder to recognize what action to take with the Most Surprised responses [the instructor might interpret the first response as conceptually incorrect (or perhaps just poorly worded)]. In the third response, the student is clearly celebrating her/his conceptual processing and perceived gains in understanding. The first two responses from Muddiest Point provide more direction for the instructor. The third

response might be interpreted as more focused on the representation in the concept question than on an understanding relative to the concepts that week.

Instructor Classroom Response to Reflection Data
The instructor provided a summary of how he used these reflection data in class. He expected that students would reflect primarily on the in-class activities. The in-class structure includes two lectures, one studio, and one recitation (where Concept Warehouse conceptual questions are answered). However, responses often referred to homework assignments and exams as well. As shown in Table 4, responses in a given week covered a broad range of topics. Sometimes a single challenging concept could be inferred from the large number of responses such as a question from the previous hour of recitation and sometimes responses referenced a concept introduced several days prior.

Most weeks, the instructor reviewed the responses in between the recitation where they were collected and the next lecture and identified common themes. In a class with nearly 300 students, reading student responses was time consuming and the time the instructor had available to review responses varied. However, the instructor thought that the review was always valuable and always identified one or more topics were to explicitly address in the next class period. This practice was felt to be critical to "closing the loop" with respect to the student feedback. By explicitly acknowledging student responses and taking corrective action, the instructor believed that students would feel they had a voice and motivated to speak candidly about aspects of the material with which they were struggling. Corrective action was generally quite simple, ranging from a few clarifying statements and suggestions for additional resources to review of previous material and additional example problems.

In reflecting on this implementation there are several changes that the instructor would recommend. First, the instructor thought it better to choose either the Muddiest Point or Most Surprised reflection and use that the entire term. He believed students started to view these as the same over time when the questions were alternated. Second, efforts should be made to ensure sufficient time (3-5 minutes) for thoughtful completion of this activity. In several instances, the activity was too rushed at the end of the class period. It became clear in reviewing the responses that if an instructor would like useful information about confusing items in a specific element of the course, the questions should be deployed with that specific intent (e.g., at the end of each class period). Ideally, there would be feedback on each aspect of the course. One could imagine a continuous dialog where these questions are asked at the end of each activity with the expressed intent of responding to the feedback in the subsequent class period. Finally, the instructor would make better use of the built-in tools in the *Concept Warehouse* (e.g., clickable word clouds) to quickly drill down into the most common responses. With a better handle on the common themes, the instructor can more effectively address the feedback during class and add value to the exercise.

Discussion
The Muddiest Point and Most Surprised reflection activities serve two purposes. First, they provide information and communication to the instructor about the attitudes,

understanding, and learning approaches of the students. This aspect allows an instructor to directly and immediately address the specific difficulties and concerns that arise. It also provides the instructor information such as how to better align upcoming content with prior knowledge. Second, the activities encourage students to reflect and be metacognitive about their own learning. Here students consider and evaluate their own learning relative to the course objectives, processes, and structures. In this aspect, it is important to consider the different ways that the language of each prompt positions the student and to consider the affective responses that may be elicited.

In balancing these purposes, it appears that each prompt has benefits. The Muddiest Point is more familiar to students and directly asks students to identify concepts that are confusing. However, Most Surprised doesn't necessarily have a negative connotation and can provide opportunity for students to reflect on and express their successes. So what should an instructor do? Of course, the answer depends on context. One response could be to do both, taking advantage of the affordances of each. Based on the findings and analysis, we suggest an alternative, shown in Figure 3. This alternative provides students the opportunity to select Muddiest Point, Most Surprised, or both. Such a strategy provides authorship to the student. It also allows an alternative prompt to those students who wish to express a positive outlook. If the class size is large enough, as the case studied here, the instructor should have sufficient Muddiest Point responses to directly identify unclear and confusing content, but also the broader pedagogical and affective responses seen in Most Surprised. We plan to implement this approach in the same class next year and study the responses.

Figure 3. Second generation reflection activity envisioned based on the results and analysis in this study.

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