A Model to Build, Assess, and Reflect on Students' Metacognition through the Classroom Debate of Controversial Environmental Issues

Matthew P. Baideme, Cristian A. Robbins, and Jeffrey A. Starke

***Abstract*— Debates have been used as a tool to promote active learning in the classroom. Role-play debates have been used to bring more realism to the issue being debated. In a junior-level environmental science course, role-play debates were utilized to present and discuss controversial environmental issues in realistic scenarios that occur throughout the United States. Using these debates as a platform, a model to build, assess, and reflect on students' metacognition was developed and implemented. This model provides a method to assess a student's metacognitive ability and allow for reflection and improvement in this area.**

***Index Terms*—environmental engineering and environmental science, metacognition assessment, debate assessment techniques, multifaceted controversial environmental issues**

I. Introduction

Classroom debates can be a tool to promote active learning in a classroom and to develop critical thinking skills of the students. Active learning in the context of a college classroom involves students in doing things and thinking about those things they are doing [1]. Research comparing lecture versus discussion techniques that are common in active learning classrooms concluded that "in those experiments involving measures of retention of information after the end of a course, measures of problem solving, thinking, attitude change, or motivation for further learning, the results tend to show differences favoring discussion methods over lecture" [2]. The use of in-class debates continues to be a common active learning technique implemented in college classrooms. A debate can be described as the process of considering multiple viewpoints and arriving at a judgment that can be applied by individuals or groups to convince others to agree with their viewpoint [3]. Debates have been successfully used in a variety of disciplines to include sociology, history, psychology, biotechnology, math, health, dentistry, nursing, marketing, and numerous other disciplines [4].

Benefits of in-class debates include promoting active engagement, which in turn improves the students' ability to master the course content. Debates allow the students to develop critical thinking skills by progressing up Bloom's (1956) Taxonomy [5]. Debates promote the higher order thinking skills of analysis, synthesis, and evaluation, which are focused on how to think as opposed to focusing on the lower order thinking skills of knowledge, comprehension, and application, which focus on what students should think [4].

Additional benefits of the use of in-class debates include the development of oral communication skills and the development of empathy. In order for students to participate and perform well in an in-class debate, they must be able to communicate effectively the salient points of their position. Debates allow students to apply oral communication skills, which are vital for success in most careers [6]. Debates allow students to practice and apply oral communication skills leading to improvement in these skills over time. The development of empathy is an important benefit of debates as well. Students must evaluate their own beliefs and possible biases on issues. Debates can help allow students to evaluate both sides of an argument and make an informed decision. Within a debate, students can be placed in a role to defend a position they oppose, which can promote empathy and allows them to transcend their own bias from another perspective [4].

Some critics of in-class debates have asserted that traditional in-class debates reinforce a bias toward dualism [7]. Traditional in-class debates typically present only two views when there might be multiple viable solutions or only one defensible point of view [4]. This type of debate format has students form a team with each team being assigned either the affirmative or the negative side of an issue and teams defend their position through constructive speeches and rebuttals [4]. A way to mitigate this bias towards dualism is to conduct a role-play debate that provides a way to promote more than two viewpoints on an issue [4]. In a role-play debate, students represent a stakeholder's views on an issue. Other

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stakeholders may align with their viewpoints on an issue but each stakeholder has their own reasons and agendas for how they side on a particular issue. This type of debate format presents a more realistic scenario to how issues are presented and argued in society, as well as providing students a greater learning opportunity.

Studies have been completed to try to determine the effectiveness of lectures as compared to debates by measuring performance in the higher order thinking skills of analysis, synthesis, and evaluation, while also trying to determine performance on the lower order thinking skills of knowledge, comprehension, and application (see Omelicheva and Avdeyeva, 2008 [9]). Additionally, various types of assessment techniques have been put forth to grade students' performance in an in-class debate. Typically, teachers utilize a rubric divided into categories such as analysis, communication, organization, etc. to assess the students' performance [4]. This type of assessment only accounts for the teacher's viewpoint on the students' performance and does not include peer or self-assessments. Walker & Warhurst (2010) [10] attempted to include self and peer assessment into the overall assessment process of students' debate performance but in a formative manner (self and peer assessments did not count towards their final grade). They did not attempt to analyze the different types of assessments to determine if there were scoring differences in how a teacher viewed a student's performance as compared to how the student's peers viewed his or her performance or how that student viewed his or her own performance.

This paper fills that void first by establishing a metric through which to assess in-class debates and then comparing four types of assessment (instructor, peer debaters, audience, and self) to determine if there were differences in how each type viewed students' performance. The differences were analyzed further by comparing the instructor, peer debater, and audience assessments to the self-assessments, which allowed for the development of a means to assess students' metacognitive ability. In the context of this paper, metacognition is the ability of an individual to assess accurately their performance through personal reflection. Improvement in metacognitive ability may lead to improved student confidence [11]. A model was developed that uses in-class role-play debates to help students build, assess, and reflect on their metacognitive ability. This model focuses on a comparison of instructor, peer, audience, and self-assessments of each student's performance within the debate. This model can be adapted to meet the needs of other universities.

II. Background

The model described in this paper was utilized over one semester by two instructors teaching three sections each of an environmental science course comprised of students majoring in environmental engineering, science, and humanities disciplines with enrollments that ranged from 13 to 19 students per section. There were 94 college juniors total across the six sections. All students majoring in environmentally focused disciplines (environmental engineering, environmental science, physical geography) typically were enrolled in the same sections with all other disciplines making up the rest. This course introduces basic environmental topics over a 40-lesson semester to provide students with a broad understanding of current global and local environmental issues and their subsequent social, economic, technological, and political impacts [12]. Four debates were scheduled throughout the semester accounting for ten percent of the total lessons taught for the course. Students' performance in the debates accounted for 30 points of the course's 1000 total points. Each debate was scheduled to coincide with the end of an instructional block of material; ecology, health, energy, and pollution. The debate served as the block's nexus by helping students connect all of the concepts using a realistic situation.

III. Metacognition Assessment Model

The main objective of this project was to assess a student's metacognitive awareness in the classroom using a role-playing debate format. A model was developed to integrate multiple types of assessment to compare a student's view on his or her performance with several other perspectives (Fig. 1).

The model was developed across two general themes. The performance thread (top of Fig. 1) is based mainly on the structure of the debate. The three phases that incorporate all of the performance measures of the debate structure are *Plan*, *Execute*, and *Reflect*. This thread incorporates a refinement loop so that lessons learned about how to perform effectively and efficiently are captured during each student's personal reflection and then transferred to the student's next assignment. The second theme is the metacognitive thread, which is based on the mental development that occurs while traversing the performance line. The three phases (*Build*, *Assess*, and *Reflect*) are nested within the actions that take place along the phases of the performance thread. A metacognitive improvement loop helps to capture all improvements in self-assessment and metacognition by connecting the student's final critical reflection with the Build phase so that they can be applied in other future situations.

A. Plan Phase

Prior to each of the debates, students were assigned a reading from *Taking Sides: Clashing Views on Environmental Issues (Fifteenth Edition)* by Thomas Easton [8]. This book presented several environmental issues each supported by two articles that discussed either a 'yes' or 'no' side for the issue. Brief commentary was provided at the beginning of each issue to give readers background information and the book's author provided a summary with discussion questions at the end of the issue. Issues that were used within the classroom debates included topics such as proposed carbon emission regulatory standards, hydraulic fracturing or 'fracking,' nuclear energy revival, and environmental law exemptions for the military.

Instead of simply dividing the class into two sides to represent the 'yes' and 'no' arguments for each issue, a more

dynamic role-playing debate format was implemented. The two course instructors developed realistic scenarios with appropriate stakeholders based on the debate topic to make the issues more relevant to the students (Fig. 2). Roles were created for each member of the debate with an attempt to include real-world stakeholders of the actual issue with varying viewpoints. This provided the students an opportunity to research real legal and environmental organizations to help formulate their decisions and opinions rather than relying on generalized or fictitious information.

Typically, five to eight students were active participants in the debates with the instructor serving as the facilitator of a town hall forum, congressional committee meeting, or other similar type of event where these issues are being debated currently in the United States. The remainder of students in the class who were not in a defined role served as audience members or voting members of a board, council, or committee, respectively. Each audience member was required to bring a critical, researched question to the debate representative of the type of question that may be seen in the settings described. This question served as their "entrance ticket" into class for that respective lesson. Each student was then expected to pose his or her question to the debaters during the question and answer period when time allowed.

Using the provided background information and debate structure, students were expected to fully prepare themselves to successfully support and defend their chosen role within the debate. This type of development during the *Plan* phase within the performance thread of the model required students to focus on the development of their knowledge about the issues at hand through personal research and discovery. It forced them to "peel back the layers of the onion" and analyze the environmental issue from several perspectives so that they could identify potential weak points of their arguments, as well as the types of arguments that the opposition may try to make. Coincident with the *Plan* phase, the metacognitive line's *Build* phase uses personal research and self-discovery to begin to build a student's metacognition by forcing the student to determine what he or she truly knows as opposed to what he or she thinks they know. This type of personal analysis will form the future basis of comparing one's personal performance to that of everyone else during the self-assessment portion of the model.

B. Execute Phase

For the conduct of the debate, students serving in a defined role were grouped with the side their role's viewpoint best aligned. This resulted in two respective sides with each having mutually supportive and nuanced viewpoints that provided counterpoints to the opposite side. The instructor served as a facilitator filling roles such as city council chairperson depending on the forum for the debate. The debate followed a modified traditional debate format to account for the time limits of the 55-minute class period, as well as to maintain audience involvement (Fig. 3).

Student performance within the debate was assessed in four areas: preparation, execution, integration, and communication. Scores were given using a 5-point Likert scale. A score of 5 indicated the assessor felt the debater excelled in the rated area, a score of 3 indicated the assessor felt the debater performed marginally in the rated area, and a score of 1 indicated the assessor felt the debater performed unsatisfactorily in the rated area. Before providing an assessment of debate performances, students were provided descriptions of the criteria to define the four areas assessed (Fig. 4). These criteria were discussed and examples of each score on the rating scale were provided so students would understand how to rate the members of the debate.

Upon completion of each debate, the instructor, the student's fellow debaters, and the non-participating audience or board members completed an assessment on each student's performance. Additionally, students assessed their own performance. Debaters provided an assessment on each of their fellow debaters and a self-assessment in the four areas described previously on a paper handout immediately after the debate. The paper handout was used so that the debaters could also provide written comments concerning the perceived strengths and weaknesses of their performance. Audience or council members not filling a graded role in the debate completed an assessment via electronic classroom response software. This technology allowed for a more interactive method of providing performance feedback and supported active learning in the classroom. Instructors used the classroom response technology to record an assessment of student debater performance based on their role. Audience or council members used the classroom response clickers to input their assessment using the 5-point Likert scale. This technology captured instant feedback on performance while it was still current in everyone's mind and, if desired, instructors could ask questions such as which role was the most convincing in the debate and provide that information to the students immediately after the debate.

Instructors compiled the data from all four assessment types to calculate a grade for student debaters. Each assessment type and area was weighted equally in the computation of a final grade. The participants were given a grade out of 20 points (the maximum points earned in the course was 1000). Audience members who did not bring a question to the debate as their "entrance ticket" were docked one-third of a letter grade from their final debate grade.

The *Execute* phase within the performance thread of the metacognitive model helps to bridge the actual execution of the debate with the audience, peer, and self-assessment that was conducted immediately following the debate. The assessment tasks were lumped into the execution phase because of their importance to the overall main objective of this model as opposed to simply holding a debate covering an environmental issue. Within this phase, students transition from the *Build* to the *Assess* phase of the metacognitive thread. The actual debate allows the student to build upon his or her understanding of what they know versus what they think they know by forcing the student to compare his or her stance with that of the opposition. A student can quickly realize that they do not know as much about their topic as originally thought

when required to develop and support a counter-argument against an opponent in the debate. The *Assess* phase is the first point where a student must contemplate where their individual performance stood in accordance with the published criteria for the four areas of assessment. By requiring the students to rate themselves, the instructors believe that they will achieve a deeper level of understanding about their metacognition and study habits when presented with the graphical comparison of assessment types, or Personal Metacognition Snapshot, during the *Reflect* phase.

C. Reflect Phase

After the instructors calculated the grades for the student debaters, instructors provided the student's grade and respective results of the four distinct assessments in a Personal Metacognition Snapshot (Fig. 5) so that they could see how their self-assessment compared to the other three assessments. Students were encouraged by instructors to reflect upon their scores in all four areas and specifically reflect upon how their self-assessment compared with the other types of assessments provided. Instructors made themselves readily available to their students to discuss their scores and how they related to their metacognitive awareness.

IV. Assessment

The instructors gathered anonymous feedback through the collection of assessments from all four debates to determine the usefulness of the metacognitive assessment model. Ratings within the electronic classroom response systems and the paper survey were submitted using a 5-point Likert scale to enumerate student responses. Data analysis was conducted in Microsoft Excel. Analysis of variance (ANOVA) and the Student's t-test were used for comparison purposes. Using these statistical tools allowed for a determination of a statistically significant difference between the debater's self-assessment and the other three perspectives. By comparing the score provided in the debater's self-assessment with the scores from the fellow debaters, audience, and instructor assessments a determination of the student's metacognitive awareness was made.

As a whole, the metacognitive assessment model provided an effective means to assess each individual student's level of metacognition. Upon the completion of each debate and subsequent tabulation of the instructor, audience, peer, and self-performance assessments, the instructors provided each student who participated as a debater in the respective debate with a Personal Metacognition Snapshot comparing their ratings (Fig. 5). This comparison served as a snapshot of how each group assessed the debater's performance compared to everyone else in the four categories: preparation, execution, integration, and communication.

In addition to the Personal Metacognition Snapshot, instructors analyzed the various ratings and provided in-depth written feedback specific to each student's performance and self-assessment. A student's overall level of metacognition was assessed by comparing the different groups' ratings within each respective category, each of which was given equal weight within the model. Statistical analysis was not conducted on each individual student's ratings to verify statistical significance due to the low statistical power provided by having very few ratings per student: one instructor; three to four peers; and ten to fourteen audience members that each contributed to their respective group's average rating of the student's performance. Rather, instructors subjectively determined where a student required additional personal reflection as opposed to those who had strong metacognitive ability. The instructors developed general categories to describe a student's metacognition, or need for additional reflection (Table I). Fig. 5a depicts a student displaying weak metacognition, or someone who could benefit from additional personal reflection within the execution area. This student rated himself as a 5.0 in terms of his execution throughout the debate. The instructor, his peers, and the audience all rated him less than a 4.0. This assessment symbolizes a need for improvement in terms of his metacognitive ability. He thought he executed far better than that which was perceived by everyone else involved in the debate.

Conversely, Fig. 5b represents a student with strong metacognitive ability. This student rated himself within 0.5 as compared to the instructor, peer, and audience average ratings for preparation and execution, as well as compared to the instructor and peer average ratings for integration and communication. This assessment symbolizes a student who understands when they truly know something as opposed to only thinking they know something. This student's reflection of his personal performance was in line with what actually took place and how those involved perceived it. Strong metacognition similar to this is a major component of lifelong learning. A student who understands their personal level of knowledge is more apt to continue learning to try to fill gaps or answer questions rather than those individuals who believe that they know or understand more than is the case. The continual quest to improve his or her metacognition will drive a student to increased levels of learning as the student progresses through life.

In addition to assessing individual performance, the model allows instructors to assess metacognitive ability at a larger scale within their course. The metacognition of all students in the course was assessed for the first debate. Scores for each type of assessment were aggregated by assessment area. Aggregated scores were analyzed using an ANOVA test to determine whether there was a significant difference ($p<0.05$) between the means (Table II). A significant difference would signify that those students' metacognition who were involved in this debate required additional personal reflection or that each individual, on average, viewed their personal performance differently than at least one other group by assessment type.

Statistical significance was achieved between the means of the types of assessment in both the Execution and Integration areas of assessment. Within these two assessment areas, a Student's t-test was used to pinpoint which types of

assessment had significantly different means. Upon further analysis, the significant differences in the Execution and Integration assessment areas were caused primarily by the comparisons between the instructor ratings and the other assessment types, which are noted by the significance attributed by the Student's t-test results (Table II). This is most likely due to students, both the debaters and audience, adjusting to the grading scheme as the instructors' ratings were lower in both cases than the other assessment types. It is also important to note that while the instructor's ratings may have been the lowest in each of the four assessment areas, the debaters' self-ratings were less than the highest in two of the areas. This shows that the students are critically reflecting on their performance rather than simply assigning themselves the highest grade. It is easy for a student to believe automatically that he/she put in maximum effort and performed flawlessly, especially when the student has not seen the final grade yet, so it is refreshing to see that the students are evaluating themselves using different lenses when reviewing their performance.

V. Discussion

A. Benefits

There were several ancillary benefits of this model other than simply providing a means to assess students' metacognition. The debate format requires that students present facts or data and subsequent analysis in front of a group of their peers. Additionally, each student must display an ability to analyze complex statements and situations in order to respond to the opposition's claims. This type of public speaking and quick analysis helps courses accomplish communication-based outcomes. Additionally, this type of activity helps engineering courses satisfy ABET outcomes (g) ability to communicate, and (j) have a broad understanding of our current contemporary issues. Students also are able to gain an appreciation for the complex nature of our current environmental problems. They learn that a simple, straightforward answer is usually not sufficient and that they need to analyze a problem from multiple lenses when developing a potential solution.

B. Challenges

This model presents two main challenges when implemented in the classroom. The first challenge is the subjectivity of the scoring system. As the model allows for instructors, student audience members, and student debate participants to provide scores, there is a certain amount of subjectivity associated with each person's opinion and overall perception. Additionally, there could potentially be outside influences depending on social dynamics between the students. Subjectivity within the assessment of performance could potentially cause the model to fail because a student's metacognition would not be accurately assessed. This challenge could be combated by infusing a discussion of the scoring scale and providing detailed representative examples of each score. We attempted to mitigate this challenge by initiating this discussion during the introduction of the debate model, as well as by providing each student a copy of a score sheet, which listed the characteristics of each scoring category and criteria for each score. Audience members were provided a copy of the score sheet at the beginning of each debate so they could take notes while listening and refer back to the criteria and characteristics during the scoring session. The second challenge involves the complacency of students. Students may be distracted, have a lack of investment, or feel that their selected score does not matter, and thus select the same score for everyone across every category. This type of scoring leads to an inaccurate score for whoever was being assessed at that point as it is not representative of their performance. Ultimately, this may lead to an inaccurate representation of a student's metacognition. This was mitigated through maintaining small class sizes, instructor involvement to ensure complete engagement by all students, and encouraging audience involvement in the debate by requiring each person to ask a question directed at a specific panel member. The question requirement ensured that all students, not just those involved in the debate, were at least doing cursory preparation and it kept them involved in the ongoing discussion achieving buy-in from most students.

VI. Conclusion

A model was presented to allow students to build, assess, and reflect upon their metacognitive ability. This model can be utilized by instructors in a myriad of academic disciplines to assess and bring improvement in a student's metacognition. The model was utilized in dynamic role-play debates that were based on realistic situations involving controversial environmental issues. Student debaters completed a self-assessment of their performance in four categories, as well as being assessed by the instructor, fellow debaters, and audience members. The results of these assessments were presented to the debater so they could reflect upon the comparison of their personal assessment to that of the other groups.

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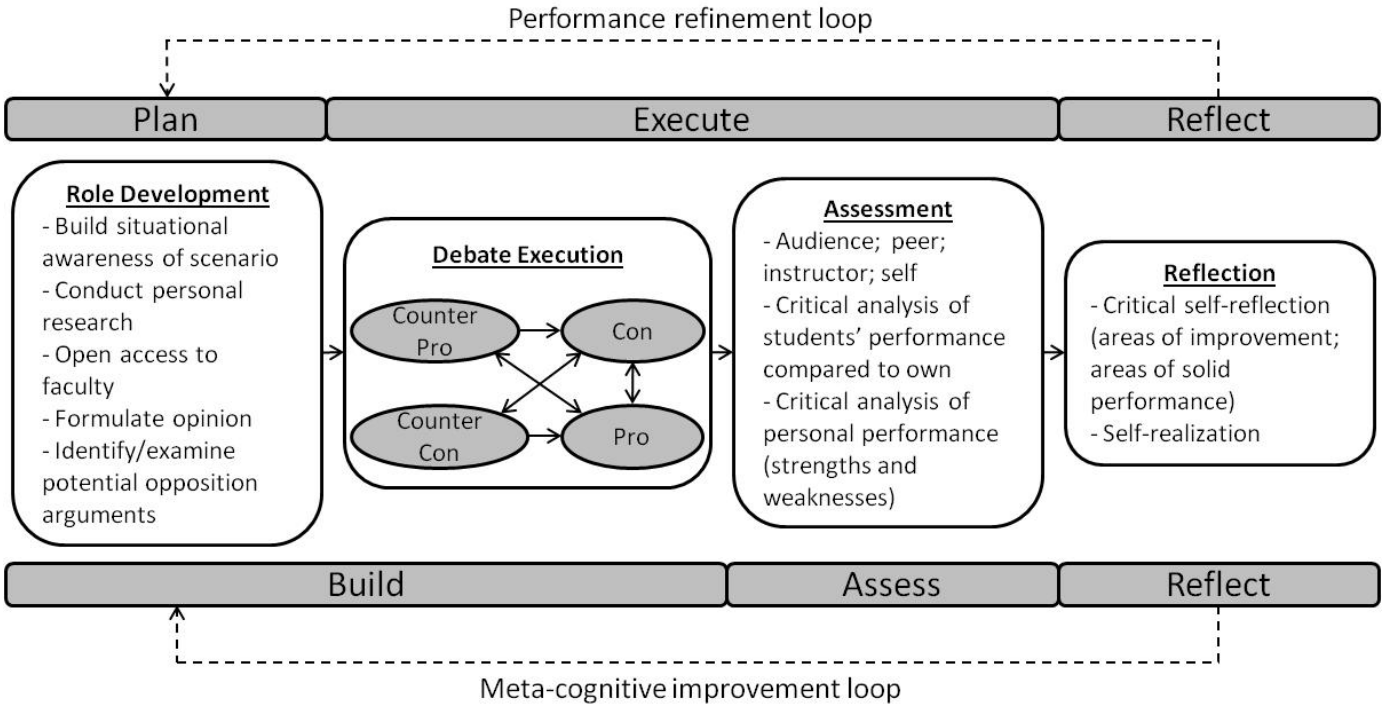


Figure 1. The metacognition assessment model provides a method to assess a student's metacognitive awareness in the classroom using a role-playing debate format. The model utilizes two themes: a performance thread that guides students' performance throughout the debate structure; and a metacognitive thread nested in the performance thread, which guides the mental development and assessment process.

Topic: Pollution
Prompt: Should the United States establish a cap-and-trade carbon emission program for large carbon emitters in accordance with California's current program?
Pro Roles: California Air Resources Board; International Emissions Trading Association Representative
Con Roles: California Manufacturers and Technology Association Advocate ; Communities for a Better Environment Advocate
Audience Perspective: The audience serves as a panel for the California Governor to hear key stakeholders' arguments within the Pacific Legal Foundation's legal appeal.

Figure 2. Instructors developed role-play debate scenarios for each of the four debates conducted. The roles shown are for the debate on carbon emission regulatory standards in California. Debaters were provided with additional information and references to further assist them in understanding their role's position.

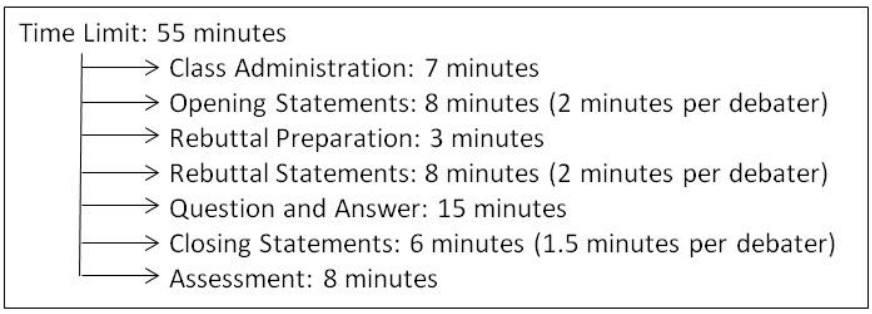


Figure 3. Instructors used a modified traditional debate format to facilitate completing the debate within the 55-minute class period. Instructors and audience/board members asked pertinent questions as well to further the debate.

1. **Preparation:** did the debater properly prepared for the debate?
   a. Detailed background information/knowledge
   b. Good organization of information
   c. Arguments are clear and orderly
   d. Incorporation of both YES and NO sides of *Taking Sides* position papers

5	4	3	2	1
Completely clear and orderly preparation	Clear preparation and orderly in most parts	Clear preparation in some parts but not overall	Some preparation but mostly disorganized	Unclear prep; disorganized throughout

2. **Execution** is the ability to support and defend the role's position.
   a. Strong, persuasive arguments
   b. Quality of explanations
   c. Utilization of facts to back up statements
   d. General coherence of statements (follow points, transitions)
   e. Analysis of *Taking Sides* position papers

5	4	3	2	1
Very strong and persuasive arguments given throughout	Many good arguments given, with only minor problems	Some decent arguments, but some significant problems	All arguments given had significant problems	Few or no real arguments given

3. **Integration** is the synthesis of multiple concepts to support or refute an argument.
   a. Integration of concepts from all of the lessons and material into his/her argument
   b. Critical analysis of all arguments and rebuttals to form a coherent counter-argument
   c. Synthesis of knowledge of course concepts with role's responsibilities to form accurate answers to arguments and questions

5	4	3	2	1
Mastery of concepts; fully integrated	Concepts largely used correctly to support arguments	Concepts used in some parts but not overall	Minimal support through concepts; little incorporation	Concepts largely unknown; no incorporation

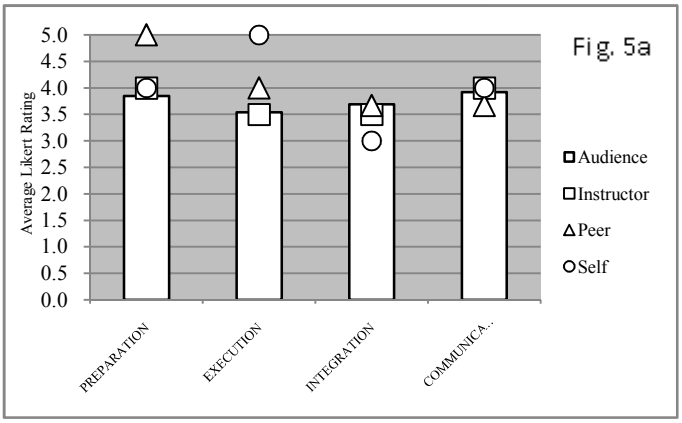
4. **Effective communication** is the general quality of delivery of the main argument, rebuttal, and answers to questions.
   a. Tone of voice, eye contact, confidence
   b. Clarity of expression
   c. Precision of arguments

5	4	3	2	1
All style features used convincingly	Most style features used convincingly	Convincing use in some parts but not overall	Few style features used convincingly	No style features used

Figure 4. Debaters were assessed in four categories: Preparation, Execution, Integration, and Effective Communication. Assessors were provided this grading rubric prior to the debate and again at the start of the debate so that they could reference the rubric during the debate and when completing their assessment on debaters at the conclusion of the debate.

Table I. Criteria for the various levels of metacognition are based upon a student's self-assessment rating compared to the other types of assessment as shown on the Personal Metacognition Snapshot. To meet each respective criterion, the difference between a self-assessment rating and at least two other ratings by assessment type must fall within the listed values.

Metacognition Level	Criteria
Strong	< 0.5
Medium	< 1.0
Weak	≥ 1.0



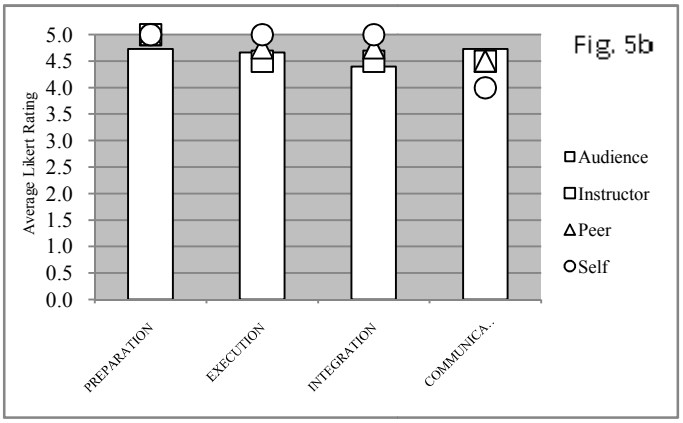


Fig. 5. Instructors provided comparisons such as these Personal Metacognition Snapshots to each student participant to present graphically an assessment of their individual metacognition. Subjective analysis was conducted with differences between the student's self-assessment (o) and at least two other assessment types of more than 1.0 signaling a need for improved self-reflection and metacognition. Fig. 5a portrays a student who requires additional reflection with respect to his or her execution. Fig. 5b represents a student with excellent metacognitive ability.

Table II. Analysis of variance (ANOVA) results with calculated means comparing types of assessment (instructor, peer, audience, self) across each assessment area (preparation, execution, integration, communication) for the first debate. The Student's t-test results were calculated only for those assessment areas that exhibited statistical significance when analyzed using the ANOVA test. Student's t-test results compare two respective assessment types.

Debate		Means				ANOVA p-value (n=38)	Student's t-test p-values (n=38)					
		Instructor	Peers	Audiences	Self		Instructor vs Peers	Instructor vs Audience	Instructor vs Self	Peers vs Self	Peers vs Audience	Audience vs Self
1	Preparation	4.01	4.31	4.23	4.25	0.302						
	Execution	3.88	4.25	4.11	4.32	0.021	0.014	0.135	0.025	0.682	0.107	0.171
	Integration	3.61	4.07	4.03	4.11	0.004	0.002	0.005	0.014	0.845	0.621	0.646
	Communication	4.07	4.31	4.29	4.07	0.253						